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Soil Survey

Puerto Rico

By

R. C. ROBERTS
United States Department of Agriculture
and party

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY
In cooperation with the
University of Puerto Rico Agricultural Experiment Station

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SOIL SURVEY OF PUERTO RICO

By R. C. ROBERTS, Division of Soil Survey, Bureau of Plant Industry, United States Department of Agriculture, and party [1]

Area inspected by MARK BALDWIN, Inspector, District 1

United States Department of Agriculture in cooperation with the University of Puerto Rico Agricultural Experiment Station

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INTRODUCTION

The detailed soil survey of Puerto Rico was started during the winter of 1928 and was continued each winter until its completion in 1936. The survey parties included from one to eight Federal men and from one to three insular men. The yearly average was a party of six. Usually the winter season started in January and finished in June. A soil survey (*16*) [2] of an area between Arecibo and Ponce was made in 1902, but since that time much additional knowledge of soils has been acquired, and it was deemed desirable to remap that area, in order that the map of the island might be consistent throughout. The original survey was neither so detailed nor so complete as the recently finished survey.

[1] The party included the following: James Thorp, L. R. Smith, C. C. Nikiforoff, A. E. Shearin, S. R. Bacon, O. C. Rogers, A. T. Sweet, Robert Wildermuth, Z. C. Foster, W. H. Buckhannan, T. E. Beesley. M. M. Striker, M. B. Marco, Ralph Leighty, Juan Juárez, Alfonso Reboyras, and V. M. Alexandrino. Division of Soil Survey, Bureau of Plant Industry, United States Department of Agriculture; and J. A. Zalduondo, D. A. Rodríguez, Jorge Landron, F. A. Villamil, G. A. Torruella, Octavio Reyes, Rafael Bird, and Ferdinand Méndez, University of Puerto Rico. The field work for this survey was done while the Division of Soil Survey was a part of the Bureau of Chemistry and Soils.

[2] Italic numbers in parentheses refer to Literature Cited, p. 492.

The purpose of the survey has been to take an inventory of all the land, determine the apparent productivity of the different soil types, and make a map of the island showing such cultural features as roads, trails, houses, schoolhouses, towns, railroads, bridges, canals, reservoirs, and cemeteries, and such natural features as soil types, streams, mountain peaks, lakes, and rock outcrops.

It was thought that, with a careful study of the soil types, better procedures for soil and crop management could be worked out in relation to the many soil types, so that higher yields could be obtained or production costs reduced. Most soil types have individual capabilities and requirements for fertilizers, kinds and varieties of crops, and cultivation practices; in fact, in many instances a special system of crop management is required for each soil, in order to obtain the maximum yields. By having a map showing the different soil types, the results of fertilizer experiments and the experiences of farmers can be classified, and the best crop and management can be found for each soil type.

This publication gives a brief description of Puerto Rico, its physiography, mineral resources, vegetation, climate, transportation, industries, agricultural statistics, soils, crops and their managements, and also the future possibilities of the crops now grown. A section on soils and crops, written in the Spanish language, also is included. For persons interested in the scientific aspects of the soils and their genesis, more detailed descriptions of the soils and a discussion of the soil-forming processes are made.

ISLAND SURVEYED

Puerto Rico is the smallest and farthest east of the four islands—Cuba, Jamaica, Hispaniola, and Puerto Rico—known as the Greater Antilles. It lies in the Torrid Zone between 17°55′ and 18°31′ north latitude and 65°39′ and 67°15′ west longitude. The latitude is about the same as that of the Sahara Desert and Bombay, India, and is slightly farther south than the southern tip of the island of Hawaii. The north-central coast of Puerto Rico is 1,400 nautical miles (1,610 statute miles) southeast of New York City, and the western part of the island is about 450 miles from the eastern point of Cuba. Ponce, on the south coast, is about 525 miles due north of Caracas, Venezuela. The island is bounded on the north and east by the Atlantic Ocean, which attains its maximum depth, 27,922 feet, about 75 miles to the north. On the south is the Mar Caribe (Caribbean Sea), which attains a depth of about 12,000 feet a short distance offshore. Canal de la Mona (Mona Passage) separates Puerto Rico on the west from the Dominican Republic, which occupies the eastern part of the island of Hispaniola.

Puerto Rico is nearly rectangular, as shown by figure 1. The greatest dimension, 113 miles (182 kilometers), is east and west, and the average width north and south is about 41 miles (66 kilometers). Including all the small islands under its jurisdiction, Puerto Rico has an area of approximately 3,435 square miles (8,896 square kilometers). The soil survey includes all the larger islands except Mona, which lies about 45 miles southwest of the mainland and has an area of about 20 square miles (52 square kilometers). The most important 2 of the 28 or more smaller islands belonging to Puerto Rico are Vieques and

Culebra. They have an area of approximately 57 square miles (148 square kilometers) and 11 square miles (28 square kilometers), respectively, and extend directly eastward from the mainland to

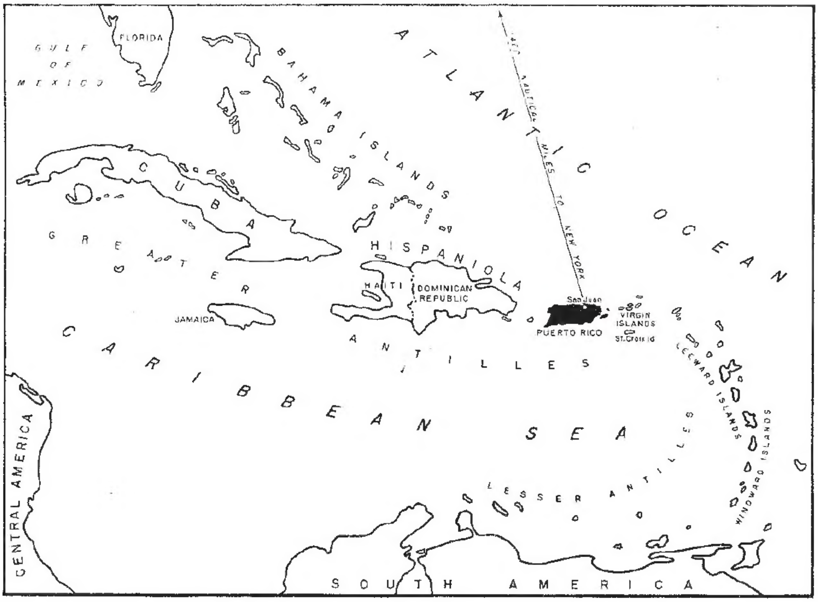

FIGURE 1.—Sketch map of the West Indies and adjacent regions, showing location of Puerto Rico.

Croquis de las Indias Occidentales y regiones adyacentes, demostrando la situación de Puerto Rico.

65°15′ west longitude. The total area of the soils mapped is 3,383 square miles, or 8,761 square kilometers.

PHYSIOGRAPHIC AND GEOLOGIC FEATURES

Puerto Rico may be divided roughly into three principal physiographic divisions, each having its own geologic relationships (fig. 2). The most extensive division consists of the complex mountain ranges which were eroded during Cretaceous time to an old, or peneplain, stage of topographic development. They were then submerged, and were overlapped during Tertiary time by the second division—the coastal plains. The sea level during that period fluctuated to such an extent that the coastal plains were exposed, eroded, and submerged, only to be exposed again and further dissected. The third division—the playa plains—includes land formed by sediments accumulated on the lower elevations during Quaternary time.

THE COMPLEX MOUNTAIN RANGES

If Puerto Rico were viewed from the air at a high elevation one would readily observe that it is divided into a northern and a southern part by an east-west mountain range, the crest of which is far to the south of a latitudinal line passing through the center of the island.

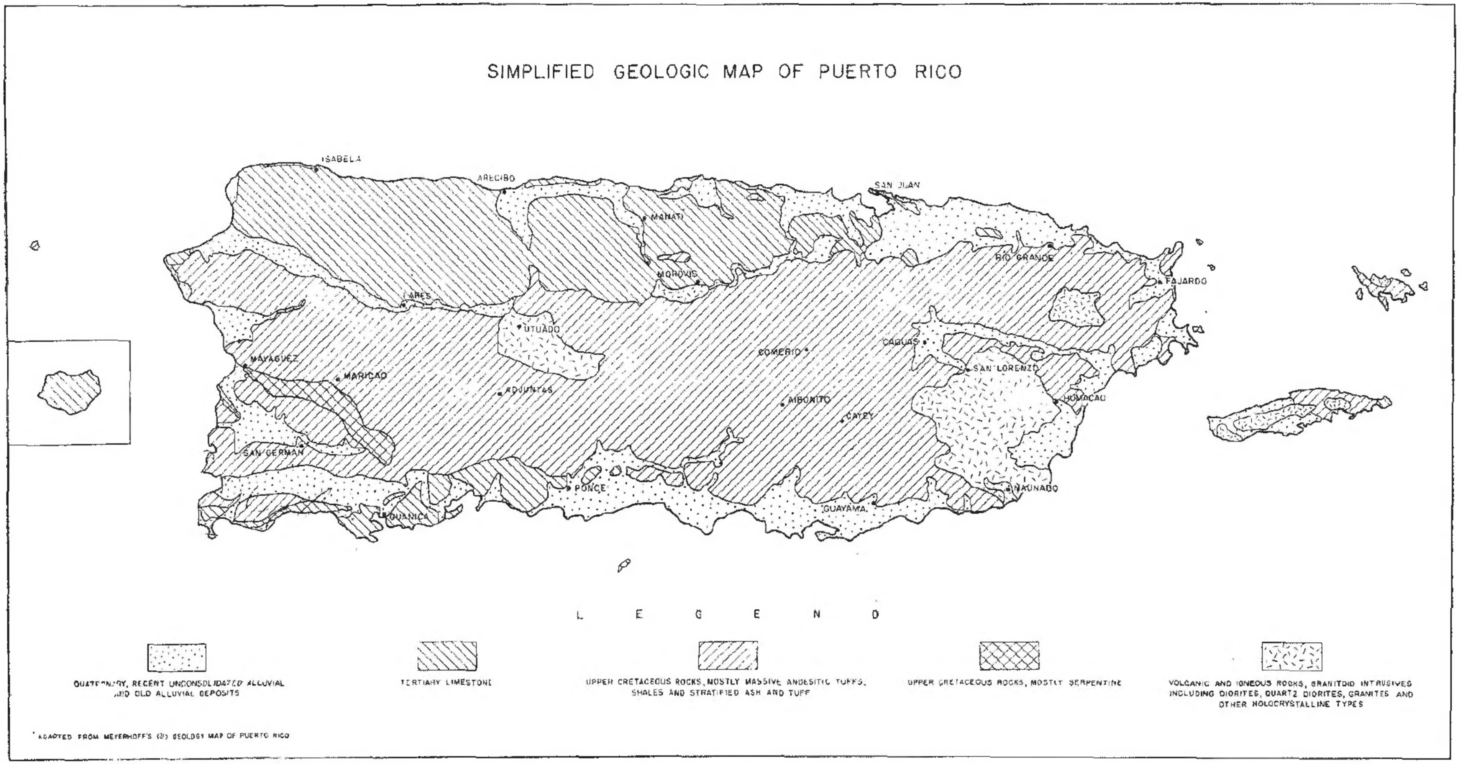

FIGURE 2.—The unconsolidated recent alluvial and old alluvial deposits largely comprise the playa plains. The areas occupied by Tertiary limestone comprise the northern and part of the southern coastal plains. The remainder of the island consists of complex mountain ranges and dissected plateaus of various rock types indicated in the legend.

Los llanos de la playa incluyen la mayor parte de los depósitos de aluvión recientes y viejos. Los llanos de la costa incluyen la mayor parte del área ocupada por la caliza terciaria. El resto de la isla constituye las cadenas montañosas complejas.

FIGURE 3.—Rain-forest vegetation in the Sierra de Luquillo; average annual rainfall about 130 inches. Soils are shallow and grayish brown on steep slope; on undulating areas they are grayish brown, underlain by light-red fairly permeable clay.

Vegetación en los bosques de las montañas de Luquillo; promedio anual de lluvia es alrededor de 130 pulgadas. Los suelos son poco profundos, de un color pardogrisáceo y en un declive escarpado. En áreas ondulantes el suelo es pardogrisáceo sobre una arcilla permeable de color rojo claro.

To the south of the crest the relief is rugged and is characterized by many steep-walled rock cliffs, abrupt high waterfalls, and jagged peaks. On the north side of the crest and extending to the coastal plain, the relief gradually becomes less rough, although there are many small waterfalls, cascades, rapids, and high mountain peaks. The main mountain range is known as the Cordillera Central in the west and Sierra de Cayey in the east. This chain extends in a northwesterly direction from Punta Yeguas (Yeguas Point) along the southeastern coast to a point near the Represa de Carite (Carite Reservoir) where the peaks attain a height of nearly 3,000 [3] feet. Thence the chain extends westward, skirting Cayey on the south, to the high rolling agricultural plateau at Aibonito. From Aibonito to a point

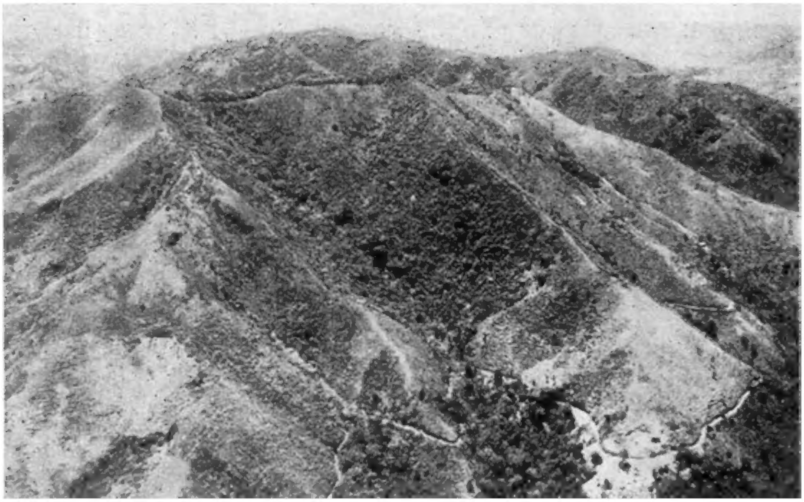

FIGURE 4.—Soil-covered slopes, Λ-shaped grass-covered ridges, and V-shaped forested ravines. The wind-protected southern and western concave slopes are better adapted to coffee, bananas, and oranges than are the wind-exposed ridges and the eastern and northern convex slopes.

Laderas cubiertas de suelo, montes en forma de Λ cubiertos de yerba, y barrancas en forma de V cubiertas de bosques. Las laderas cóncavas al sur y al oeste protegidas del viento están mejor adaptadas para la siembra de café, guineos y chinas (naranjas) que aquellas convexas hacia el este y el norte, expuestas al viento.

west of Orocovis the peaks are numerous, steep, brush covered, and range in elevation from 3,000 to 3,300 feet. West from Orocovis to Monte Guilarte (Mount Guilarte) the range becomes more rugged, heavily forested, and more sparsely populated. Cerro de Punta, the highest peak (4,398 feet above sea level), is about 4 miles south of Jayuya and is near the center of this rugged area. From Monte Guilarte to sea level at Mayagüez the elevation gradually decreases, the relief becomes less rough, and more agricultural crops, especially coffee and oranges, are grown.

The less extensive chains of the complex mountain ranges consist of the prominent rocky, steep, sparsely populated, forest-covered Sierra

[3] All elevations are taken from a map (Porto Rico and Contiguous Islands under its Jurisdiction) published by U. S. Dept. Agr. Forest Service, R-8. (Revised by L. I. Neiman, 1935.)

de Luquillo (Luquillo Mountains) 2,500 to 3,500 feet high (fig. 3), in the eastern end of the island, and the less conspicuous lower highly eroded thickly populated grass- and minor-crop Atalaya range, culminating in Pico Atalaya (Atalaya Peak) in the northwestern part. In addition to these ranges, there are many smaller ranges separated by agricultural valleys and hills.

This extensive physiographic division is characterized by steep soil-covered slopes (fig. 4), Λ-shaped ridges, and V-shaped ravines that gradually change toward the coastal plains and interior valleys to gently rolling hills and sloping ravines. The hills and mountain ranges do not have a uniform definite trend as do the hills in the coastal plain along the northern coast, but they have been deeply dissected by a dendritic system of stream development, and many of the divides are separated by gorgelike valleys ranging from 500 to 1,000 feet in depth. Many excellent dam sites for hydroelectric plants occur along the rapid-flowing rock-bottom mountain streams (fig. 5).

Figure 5.—Rapid-flowing mountain stream, which affords excellent sites for dams for hydroelectric plants.

Torrente en un monte; sitio excelente para una presa de planta hidroeléctricas.

Practically all of the streams head in the area occupied by this physiographic division. Some of the rivers are very large, but none is navigable except for small boats. The largest waterways are the Río Grande de Loíza (Loíza River), Río de la Plata (Plata River), and Río Grande de Arecibo (Arecibo River). All these flow north to the ocean. The Río Culebrinas (Culebrinas River) flows west, following the limestone escarpment from a point near Lares to the western coast; and the Río Grande de Añasco (Añasco River) drains a large part of the west-central area. The streams flowing to the southern coast resemble the streams in the western plains of the United States, as they generally are dry many months of the year. Those flowing to the eastern coast are short but flow continuously. The beds of the larger streams, both in the humid and arid sections range from 100 to 175 feet in width, and the height of the banks ranges from 4 to 20 feet. Most of the stream beds through the uplands are strewn with large boulders, but only in the arid southern section are large boulders abundant in the stream channels throughout the river flood plains. During floodtime some of the streams discharge (*49, p. 26*) from 10,000 to 20,000 second-feet

of water. Even during the dry seasons, some of the streams in the humid area discharge from 250 to 1,500 second-feet.

Geologically, the complex mountain ranges are of volcanic origin, but not in the same degree as the ranges on the volcanic islands of Hawaii and Martinique. Meyerhoff (*31*) has written an extensive description of the geology of Puerto Rico. The most abundant and widely distributed rocks are volcanic tuffs and shales, many of which contain some igneous intrusive, generally andesitic in composition. The tuffs and shales contain a very small quantity of quartz. Therefore, the weathering of these rocks produces a soil that is high in clay, medium low in silt, and low in sand. The rocks have weathered to a depth ranging from 20 to 60 feet on level or rolling relief in areas of high rainfall. The development of the soil and the weathering of the rocks depend to a great extent on the character of the soil climate, which is the product of air climate and local conditions. The more

FIGURE 6.—Granite boulders strewn over the surface of Pandura loam, smooth phase. Making charcoal to the right on typical Pandura loam. Múcara soils in background.

Rocas graníticas regadas por la superficie del Pandura lómico, fase lisa. A la derecha haciendo carbón en un Pandura lómico típico. Suelos Múcara al fondo.

water and heat that penetrate to the rock, the greater the weathering process and the thicker the soil. Even in areas having very high rainfall, if the slopes are so steep that only a small quantity of water remains in contact with the rocks for any length of time, the soil is shallow. In fairly dry areas, if the surface is level or slightly depressed, the rock in general is weathered to a greater depth than on slopes in areas having a higher rainfall.

Granite ranks next in extent to tuffs and shales in the composition of the complex mountain ranges. It is localized chiefly in two rather large areas, one covering nearly 100 square miles in the vicinities of Juncos, Yabucoa, and Patillas, the other including about 30 square miles between Utuado and Jayuya. The larger area is characterized by two distinct separations, as follows: (1) Steep, eroded slopes with numerous smooth hard granite boulders, some of which are 20 feet in diameter, strewn over the surface (fig. 6). Some of the peaks in this area are nearly 2,000 feet high, but most of the land is below the

1,500-foot contour line. (2) The more rolling areas, which range in elevation from 250 to 1,000 feet and are rock-free, moderately eroded, but intensively cultivated. The small granite area near Utuado is characterized by short steep severely eroded stone-free cultivated hillsides and grass-covered knife-edged ridges, very few of which attain an altitude of more than 1,500 feet. Most of the granite rock in Puerto Rico is a coarse-grained quartz diorite that weathers into a friable well-drained and well-aerated soil that requires yearly fertilization. In most granite areas, the drainageways are U-shaped rather than V-shaped, as is characteristic in other areas of the island. Houses are numerous in these areas, especially so on those of more rolling relief.

In addition to the tuff, shale, and the granite igneous intrusions, a fairly large area of serpentine rock occurs in the west-central part of the island, extending from a point northwest of Yauco to the coast near Mayagüez. This rock produces soils that are less erodible than the products of other rocks, and most of the hills are conspicuous in that they extend above the surrounding land, forming high rounded ridges. Where soils from this rock occur, vegetation is scanty and there are very few houses. Extensive landslips and pronounced creeping occur on the steep slopes. The rock is smooth, like talc, and platy, and when an unusual quantity of rain falls, the rocks slide easily over the surface of each other, causing a part of the hillside to tumble down.

Another rock of the complex mountain ranges is the Cretaceous limestone which is conspicuous in the few areas in which it occurs, owing to the steep or precipitous relief and lack of stream channels. Water readily penetrates the limestone to underground streams. Soils derived from this rock are not well adapted to agriculture because they are rocky, shallow, and have unfavorable relief. The largest areas of this kind are east of Juana Díaz, near Lajas, in the vicinities of Cayey and Orocovis, and near La Muda.

Besides the above-mentioned rocks, conglomerates and agglomerates are associated with the tuffs and shales in many parts of the island.

COASTAL PLAINS

The coastal plains parallel nearly the entire coast line. They range in width from a maximum of 13 miles (21 kilometers) at Lares to nil at several points along the eastern and western coasts. On the north coast they include most of the area north of the towns of Loíza, Río Piedras, Corozal, Ciales, Lares, San Sebastián, Moca, and Aguadilla. On the south coast they are much less extensive. Here, they include a part of the area south of Boquerón, Lajas, Yauco, Guayanilla, Peñuelas, Juana Díaz, Baños de Coamo (Coamo Springs), and Guayama. On the east and west coasts they cover but a few square miles. Most of the coastal plains are confined to areas that were submerged during Tertiary time and covered by a thick deposit of limestone. Since that time there have been several fluctuations in sea level, causing the landscape to have a belted appearance.

The outstanding characteristic of the northern coastal plain is the horizontal east-west deposit of limestone, which develops into distinct topographic belts according to the composition of the limestone. This limestone area is a plateau in a youthful stage of dissection, so

FIGURE 7.—See legend on page 11.

far as stream erosion is concerned, but the relief in some of the limestone belts is the roughest of the island, because the underground solution has caused sinkholes, caves, and numerous precipitous cliffs, making some areas nearly impossible to penetrate, even by foot. Both surface and subterranean erosion are still active. From a maximum elevation of about 1,500 feet near Lares, the northern coastal plain gradually slopes to sea level along the northern coast.

The most southerly belt of the northern coastal plain occupies an almost continuous narrow strip from a point near Corozal to a point near San Sebastián. This belt is characterized by comparatively pure calcium carbonate rocks and massive reef beds that have open porous textures, making it possible for the forces of erosion to form conspicuous high cone-shaped mogotes (haystacks) and long narrow pepino (cucumber-shaped) hills (fig. 7). Almost all of the pepino hills have a northeast-southwest trend and are about two-tenths of a mile long; none of them is very flat or broad on the top. Between the hills are numerous small long narrow undulating valleys. Drainage water makes its way to the small valleys and sinkholes, thence along underground passages to the few streams that have cut deep gorgelike valleys across this formation. Houses are fairly numerous in the small valleys, but only a few dot the hilltops. Trees are scarce except near dwellings and along the drainageways.

The southern limit of this belt has a very definite escarpment several hundred feet high (fig. 7). It is characterized by a nearly uniform east-west unbroken line, except where rivers flowing from the mountains have cut through the limestone formation, forming large triangular-shaped indentations with the apex pointing downstream and terminating in a gorge. The Ríos Guajataca, Camuy, Tanamá, Grande de Arecibo, Manatí, and Cibuco have cut through in this manner. The Río de la Plata terminates in a flood plain. Directly back of the escarpment, occurring from one end of the limestone areas to the other, and also in lowland valleys within the limestone section, are inner plains that range in width from a few feet to a mile or more. The soil contains considerable basal gravels and probably is derived from lower Tertiary shale. Wherever this material occurs there are many surface drainageways which abruptly sink where the material joins the limestone hills. In this area some of the land is nearly level, but most of the hills are dissected by drainageways.

North of the southernmost limestone belt is another limestone formation extending from the Río Guajataca eastward to a point south of Esperanza, thence from a point east of the Río Manatí to a point near Corozal. In this formation the steep mogotes are absent and the relief is rolling or undulating (fig. 8). The limestone is white and semicrystalline, with some chalky seams. All the rain water drains to numerous deep sinkholes, thence into the subsurface streams. Throughout

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FIGURE 7.—Vertical aerial view of the southern escarpment of the north-coast limestone area along the Río Grande de Arecibo. The conspicuous long narrow pepino (cucumber-shaped) hills are gradually weathering into many cone-shaped hills. (Photograph taken by U. S. Navy.)

Vista aérea vertical de la escarpa sur del área caliza de la ccsta norte a lo largo del Río Grande de Arecibo. Las colinas largas y estrechas llamadas pepinos (en forma de pepinos), se están gradualmente convirtiendo en muchas colinas cónicas. (Fotografía tomada por la Marina de los EE. UU.)

FIGURE 8.—See legend on page 13.

this limestone belt, houses are numerous and farms are small, few of them more than 10 acres in extent. There are very few trees throughout this area, except along fence lines.

Adjacent to this limestone belt on the north and extending to the west and east is another distinct limestone belt which extends from a point near Aguada north almost to Aguadilla, thence eastward in a narrow strip to the Represa de Guajataca (Guajataca Reservoir), thence in wider areas to Florida, Corozal, Toa Alta, and Central[4] Canóvanas. This belt is similar in relief and drainage to the southernmost belt, but it does not include so high a proportion of steep land and most of the hills have longer and more gentle slopes that are better suited for cultivated crops. Houses dot the hilltops and the narrow valleys.

The next limestone belt on the north, which extends from Aguadilla to Toa Alta, is characterized by spectacular, rugged, brush-covered mogotes and sinkholes. The general trend of the individual hills, or mogotes, is northeast to southwest. Drainage is effected through the numerous sinks, which in time may become united by the caving and dissolving of the adjacent limestone. Small dwellings are fairly numerous on the hills and valleys; they are located in many places without much regard to accessibility or nearness to the limited water supply. Foot and horse trails are the only means of travel through most of this country, and some of the rougher parts are hardly passable for the sure-footed small horses and mules.

The most northern of the large limestone belts is characterized by uniformly stratified beds of hard flinty limestone alternating with soft gray limestone. Most of the limestone rock of the mogotes in this belt is pitted with holes and has many irregularities (fig. 9); it is very dense and hard and will ring when hit with a hammer. Characteristic features of this belt are the long east-west chains of saw-toothed, jagged, tree-covered mogotes and the nearly level, densely populated rather wide valleys. This belt extends from the northwestern corner of the island to a point east of Loíza. From Bayamón to a point near Loíza only a few limestone hills are exposed. Some of them rise abruptly above the alluvial land and muck areas, where weathering of the limestone has been complete. In the northwestern part of the island this limestone belt terminates abruptly, forming high sea-girt cliffs. Most of this area has subterranean drainage, and consequently water for domestic purposes is scarce.

Fringing the northern coast at low elevations is another narrow intermittent belt of limestone. It is characterized by scattered ridges of calcareous sandstone that probably have been formed by a com-

FIGURE 8.—Vertical aerial view of the smooth grass-covered limestone hills in the foreground and the fields of sugarcane on the soils of the lower Tertiary plains, which abruptly join along the small stream. Land on one side of the stream is valued at $175 an acre and on the other side at $5. (Photograph taken by U. S. Navy.)

Vista aérea vertical; las colinas calizas cubiertas de yerba al frente y los campos de caña en suelos de los llanos Terciarios, se juntan abruptamente a lo largo del riachuelo. La tierra a un lado del riachuelo está valorada a $175 por acre y al otro lado a $5. (Fotografía tomada por la Marina de los EE. UU.)

[4] Central refers to a large surgarcane mill and adjacent land.

bination of a slight uplift of the shore line and the drifting action of the trade winds.

The coastal plain on the south side of the island has no definite limestone belts, but a large percentage of its area overlies Tertiary limestone, and it has a much higher proportion of old alluvial-fan material than the northern coastal plain. Most of the alluvial fans are in the east-central part or between Ponce and Patillas.

FIGURE 9.—Hard dense Tertiary limestone which weathers slowly, producing acid red soils of the Tanamá, Bayamón, and related series.

Piedra caliza Terciaria sólida y densa; esta piedra se desintegra lentamente y produce suelos rojos ácidos de las series Tanamá, Bayamón, y otras series relacionadas.

The limestone hills range from gently rolling to steep, and the many intervening plains or valleys are undulating and fairly wide. Most of the drainage of the limestone section is subterranean. The elevation of this area ranges from a few feet to more than 500 feet above sea level.

The largest area of the coastal plains in the eastern part of the island is near Ceiba. This is a broad nearly flat or undulating plain which is crossed by very few drainageways. Similar topographic positions occur in the intermountain valley east from Caguas, as well as in small areas on the west coast near Faro Cabo Rojo (Cabo Rojo Lighthouse), Boquerón, Puerto Real, and Joyuda. These areas range from a few feet to 100 or more feet above sea level. Most of them are densely populated.

PLAYA PLAINS

The playa plains include the level alluvial flood plains, the lagoon deposits, and the elevated beach sands. The flat alluvial flood plains occupy the largest area and comprise the most valuable agricultural land. They occur along all the streams but are most extensive near the mouths of the larger rivers. In a great many places the shape of the plain is triangular, with the apex pointing upstream. The alluvial deposits terminate abruptly against the upland hills. The soils are developed from transported material and, therefore, range in texture from coarse sands to clay. They occur at low elevations, generally not more than 10 feet above sea level. The land is so valuable that few houses are built on it. In most places natural drainage is supplemented by artificial drainage systems.

Nearly the entire coast line is fringed by a low, almost level, sandy beach, which ranges in width from a few feet to more than a mile. The coastal beach material consists of shells, coral, lime carbonate, and sand. In places sand dunes, a few of which are 20 feet high, occur

at or near the beach. In many places, depressions or lagoons, slightly below sea level, containing salt water or salt-marsh vegetation, occur inland a short distance from the dunes. Adjacent to the lagoons are old estuary clay or silty clay deposits which gradually merge, toward the rivers, with well-drained alluvial land. Many of the estuary deposits are only slightly above sea level and unless drained are under water several months of the year. The mouths of most of the streams emptying into the ocean are choked by sand bars, and these have helped to form the adjacent swamp areas.

Puerto Rico has several small natural lakes and a few large reservoirs. The lakes occur within the coastal lowland, and the reservoirs are located on the upland, most of them in the high mountains. The larger lakes are Lago Tortuguero, Laguna Cangrejos (Torrecilla), and Lago San José along the northern coast; Laguna de Guánica near the southern coast; and Lago Joyuda on the west coast. Lago Tortuguero, a fresh-water lake embracing an area of about 2 square miles, is the largest. All the other lakes are shallow and contain salty water, except Laguna de Guánica, in which the water is only brackish. As they have outlets to the nearby waters of the ocean, most of the lakes are affected by the tides.

Represa de Guajataca, the largest reservoir, is situated between the limestone hills of the coastal plains, and its waters are used to irrigate the land near Isabela. The water from all other reservoirs used for irrigation purposes is diverted to the south coast.

The island has many bays, some of which are well protected from the waves and have very quiet waters, with mangrove swamps extending to the water's edge. Puerto de San Juan (San Juan Bay) offers the finest harbor for ships.

MINERAL RESOURCES

Mineral resources seem to be limited in extent and value. Some of the rocks, especially the Cretaceous limestone, have high value as road-building material. This rock is hard, yet crushes fairly easily and has binding qualities superior to those of most of the other rocks. The semicrystalline Tertiary limestones are good for road material, but they are generally interbedded with chalky lime which is soon worn away when placed on a road and subjected to heavy traffic. The tuffs crumble too readily for road material, and the other volcanic rocks are either too hard for crushing or are not sufficiently indurated. Some andesites are used for road material.

Some of the chalk lime is used commercially for the liming of acid soils. Many thousands of acres in the interior could be greatly improved by an application ranging from 2 to 4 tons of lime to the acre. The addition of lime not only helps the physical condition of the soils, but it increases the yield of crops and probably improves the nutritive value of the grains and grasses produced. Almost any of the limestones occurring on the island is effective if it is finely ground. Some limestone, however, contains a fairly high content of phosphorus and therefore is more valuable as a soil amendment than are other calcareous rocks. The lime most commonly used comes from Cayo Icacos (Icacos Island), northeast of Fajardo. It is used on soils and for the sedimentation of impurities in the manufacture of sugar.

Some of the Tertiary limestone should make good building stone as it is rather easily worked into blocks and is fairly resistant to weathering.

The white silica sand, which occurs in large quantities near the line of the American Railroad Co. of Puerto Rico south and east of Lago Tortuguero, and in other areas along the northern coast from Santurce to the Río Camuy, may at some future time be used in the manufacture of glassware or sodium silicate.

The deep soils derived from serpentine rocks should have good possibilities for the mining of iron, chromium, and nickel, as they are very high in the first and moderately high in the other two minerals.[6] This kind of land (Nipe clay and Rosario silty clay) occupies 27,904 acres southeast of Mayagüez and near Punta Guanajibo.

Northeast of Juana Díaz, a deposit of manganese ore in Cretaceous limestone yields an annual production (*10, p. 5*) of about 2,500 tons.

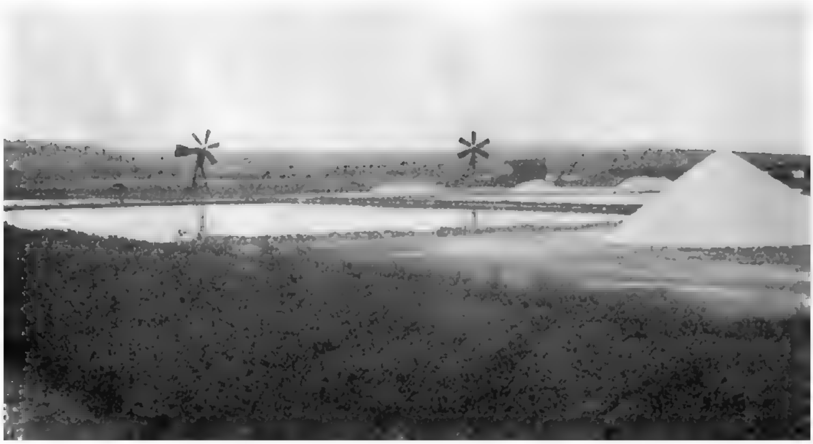

FIGURE 10.—Salt pans and piles of salt in the arid region along the south coast. Montones de sal y cristalizadores en la región árida a lo largo de la costa sur.

Other manganese deposits are south of Aguada, Adjuntas, and Corozal. Some magnetite has been found near Las Piedras. A few thin veins of lignite outcrop near San Sebastián, but they are not being developed. Some copper is mined south of Aguada, and placer gold mining has been carried on near Corozal for a number of years. Some gold has been found near Hacienda Catalina, Lares, Sabana Grande, and Guayama. A total of $100,000 worth of gold was mined between 1900 and 1932 (*10, p. 7*).

Sea water is evaporated to produce salt in fairly large quantities on the south coast adjacent to the sea. The quantity obtained annually depends on the size of the pans and the length of the rainless periods. The working season is during the winter and spring. In most places the water is pumped into the pans by large fan windmills (fig. 10). When the water has evaporated the salt is scooped into wheelbarrows and then dumped into piles until hauled by truck to local markets. This industry has been profitable during recent years, and the area devoted to it has greatly increased.

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[6] Chemical analysis of a sample of Nipe clay appears on p. 475.

A small quantity of bat guano fertilizer is obtained from some of the caves in the Tertiary limestone, especially on Mona Island.

Several of the soil types, especially Catalina clay and Alonso clay, should make very good bricks. Indian pottery found on Las Mesas near Mayagüez is of good quality, indicating that Nipe clay also should be good for making bricks and pottery. The granite boulders in the Pandura soils should make very good building stone.

VEGETATION

Most of the present native vegetation undoubtedly is different from the plant life that existed during Cretaceous or even Tertiary periods. The introduction of plants into Puerto Rico, through the aid of man, probably was started by the Caribs and the Arawaks long before Columbus landed in 1493, and it has continued to the present time. The ever-changing environment has had its effect on the different species, as also has the destruction of the original forest, which exposed the soil, increased evaporation, and tended to make a drier soil climate. The second-growth vegetation was slightly different from the virgin trees, as it has had to be more drought-resistant in order to survive.

The native vegetation is very closely related to the soil climate. On droughty land, such as coarse sands, very steep hills, shallow soils, or very permeable soils, the vegetation in many places is more typical of a drier climate than that of the surrounding air climate. On the other hand, slight depressions, poorly drained soils, or swamps, even in arid regions, have a plant growth characteristic of a moist climate.

The names of the plants generally used throughout this report are those in most common use—some are English, and some are Spanish. The botanical names and the corresponding English and Spanish common names (taken mostly from Otero and Toro (*33*)) of nearly all of the plants mentioned are listed in table 1.

TABLE 1.—*Important plants growing in Puerto Rico*

Botanical name	English name	Spanish name
Acacia farnesiana	Casha	Aroma casha.
Achras zapota	Naseberry; sapodilla	Níspero.
Acrocomia aculeata	Corozo palm	Palma de corozo.
Acrostichum aureum	Acrostichum fern	Helecho.
Agati grandiflora		Gallito.
Agave americana	Centuryplant	Maguey.
Agave sisalana	Sisal hemp	Sisal.
Amomis caryophyllata	Bay rum tree	Malagueta.
Anacardium occidentale	Cashew nut	Pajuil.
Ananas sativus	Pineapple	Piña.
Andira inermis	Angelin tree; cabbage tree	Moca.
Andropogon virgatus		Rabo de ratón.
Annona reticulata	Custard-apple	Corazón.
Annona muricata	Soursop	Guanábana.
Arachis hypogaea	Peanut	Maní.
Artocarpus communis	Breadfruit	Palo de pan.
Athyrocarpus persicariaefolius		Cohitre blanco.
Avicennia nitida	Black mangrove	Mangle bobo.
Bambusa vulgaris	Bamboo	Bambú.
Batis maritima	Saltwort	Barilla.
Bromelia pinguin		Maya.
Buchenavia capitata	Yellow sanders	Granadilla.
Bucida buceras	Black olive	Húcar; úcar.
Cactus intortus	Turkscap	Melón de costa.
Cajanus cajan	Pigeonpea	Gandul.
Callisia monandra		Cohitre morado.
Calophyllum antillanum	Galba	Santa María; María.
Calotropis procera	Giant milkweed	Algodón de seda.

TABLE 1.—*Important plants growing in Puerto Rico*—Continued

Botanical name	English name	Spanish name
Caesalpinia sepiaria	Wait a bit	Zarzade cercas
Capparis coccolobifolia	Broad-leaved caper tree	Burro.
Capparis flexuosa	Caper tree	Palo de burro.
Carica papaya	Papaya	Lechoza.
Caryophyllus jambos (*Eugenia jambos*)	Rose apple	Poma rosa.
Castalia ampla	Waterlily	Flor de agua.
Casuarina equisetifolia	Australian pine	Pino Australiano.
Cecropia peltata	Trumpet tree	Llagrumo.
Cedrela odorata	Spanish cedar	Cedro.
Ceiba pentandra	Silk-cotton tree	Ceiba.
Cenchrus echinatus	Sandbur	Abrojo.
Cephalocereus royeni		Sebucán; dildo.
Chloris inflata	Mexican bluegrass	Horquetilla morada.
Chrysobalanus icaco	Coco-plum	Icaco.
Citrus grandis	Grapefruit	Toronja.
Citrus medica	Citron	Cidra.
Citrus sinensis	Orange	China.
Cladium jamaicense	Sawgrass	Serrucho.
Clusia rosea	Balsam fig	Cupey.
Coccoloba uvifera	Seagrape	Uva de playa.
Cocos nucifera	Coconut	Palma de coco.
Colocasia esculenta	Elephant ear	Malanga.
Colubrina reclinata	Nakedwood	Mabí.
Conocarpus erecta	Buttonwood	Mangle botón.
Cordia alliodora	Spanish elm	Capá prieta.
Cordia sulcata		Moral.
Crescentia cujete	Calabash	Higüero.
Crotalaria juncea	Crotalaria	Crotalaria.
Cucurbita moschata	Squash	Calabaza.
Cyathea arborea	Treefern	Helecho arborescente.
Cynodon dactylon	Bermuda grass	Grama; yerba Bermuda.
Cyperus giganteus		Junco de ciénaga.
Cyperus rotundus	Nutgrass	Coquí.
Dacryodes excelsa	Candlewood	Tabonuco.
Delonix regia	Flametree (royal poinciana)	Flamboyant.
Dendropogon usneoides	Spanish-moss	Barbas de úcar.
Dioscorea cayenensis	Yellow yam	Ñame de Guinea.
Dioscorea esculenta	Potato yam	Ñame papa.
Dioscorea rotundata	White Guinea yam	Ñame de Guinea blanco.
Dioscorea trifida	Indian yam	Mapuey.
Cassia occidentalis	Coffee senna	Hedionda.
Elaphrium simaruba	Gum tree	Almácigo.
Erythrina corallodendrum	Red-bean tree	Bucare.
Euterpe globosa	Mountain palm	Palma de sierra.
Ficus laevigata	Wild fig	Jagüey.
Fimbristylis diphylla		Junquillo.
Gaussia attenuata		Llume.
Gossypium barbadense	Cotton	Algodón.
Guaiacum officinale	Lignumvitae	Guayacán.
Guaiacum sanctum		Guayacán blanco; guayacanillo
Guarea guara	Muskwood	Guaraguao.
Hymenaea courbaril	West Indian locust	Algarrobo.
Inga vera		Guaba.
Inga laurina	Pomshock	Guamá.
Ipomoea batatas	Sweetpotato	Batata.
Laguncularia racemosa	White mangrove	Mangle blanco.
Lantana involucrata	Button sage	Santa María.
Laplacea portoricensis		Maricao.
Leptocereus quadricostatus		Sebucán; pitajaya.
Leptoglottis portoricensis		Zarzarilla.
Magnolia splendens		Sabino.
Mammea americana	Mammee apple	Mamey.
Mangifera indica	Mango	Mango.
Manihot esculenta	Cassava	Yuca.
Marcgravia rectiflora		Bejuco de palma.
Marcgravia sintenisii		Bejuco de rana.
Melinis minutiflora	Molasses grass	Yerba melado; yaraguá.
Meliosma obtusifolia		Cerrillo.
Mimosa pudica	Sensitiveplant	Sensitiva; moriviví.
Mimusops nitida	Bulletwood	Jácana.
Musa paradisiaca	Plantain	Plátano.
Musa paradisiaca sapientum	Banana	Guineo.
Nicotiana tabacum	Tobacco	Tabaco.
Ocotea spathulata		Granadillo.
Olyra latifolia		Carrucillo.
Opuntia dillenii	Pricklypear	Tuna brava.
Panicum purpurascens	Para grass	Malojillo.
Panicum maximum	Guinea grass	Yerba de Guinea.
Paspalum virgatum		Cortadero.
Pennisetum purpureum	Napier grass; elephant grass	Yerba elefante.
Persea americana	Avocado (alligator pear)	Aguacate.
Phaseolus vulgaris	Bean	Habichuela.
Philoxerus vermicularis	Saltweed	Yerba de sal.

TABLE 1.—*Important plants growing in Puerto Rico*—Continued

Botanical name	English name	Spanish name
Phragmites communis	Common reed	Caña de indio.
Pithecolobium unguis-cati	Blackbead	Escambrón colorado.
Prosopis chilensis	Mesquite	Mezquite.
Psidium guajava	Guava	Guayaba.
Pterocarpus officinalis		Palo de pollo.
Quercus thompsonii	Oak	Roble.
Randia mitis	Box brier	Tintillo; escambrón.
Rhizophora mangle	Mangrove	Mangle.
Roystonea borinquena	Royal palm	Palma real.
Rubus rosaefolius	Mountain raspberry	Fresa.
Saccharum officinarum	Sugarcane	Caña de azúcar.
Schizachyrium brevifolium		Serrillo dulce.
Sechium edule	Chayote	Tayote.
Sesuvium portulacastrum		Verdolaga rosada.
Sideroxylon foetidissimum		Ausubo.
Solanum tuberosum	Potato	Papa.
Spathodea campanulata	African tuliptree	Tulipán africano.
Spondias mombin	Hog plum	Jobo.
Sporobolus indicus	West Indian rush grass	Matojo.
Sporobolus virginicus		Matojo de playa.
Stenotaphrum secundatum	St. Augustine grass; running crabgrass.	Grama blanca.
Swietenia mahagoni	Mahogany	Caoba.
Tabebuia rigida		Roble de sierra.
Tamarindus indica	Tamarind	Tamarindo.
Terminalia catappa	Tropical almond (West Indian almond).	Almendro.
Theobroma cacao	Chocolate tree	Cacao.
Tragus berterionanus	Pricklegrass	Hincadora.
Typha angustifolia	Cattail	Aneas.
Tillandsia recurvata	Air plant	Nidos de gungulén.
Tripsacum laxum	Guatemala grass	Yerba Guatemala.
Triumfetta lappula		Cadillo.
Vigna unguiculata	Cowpea; black-eyed pea	Frijol.
Xanthosoma atrovirens	Yautia; dasheen; tania	Yautía amarilla.
Zea mays	Indian corn	Maíz.

Some of the most common plants that grow throughout nearly all parts of the island are flamboyant, maya, almendro, hedionda, Australian pine, bamboo, and such commercial crops as bananas, plantains, oranges, grapefruit, pineapples, sugarcane, tobacco, corn, beans, yuca, yautia, sweetpotatoes, mangoes, pigeonpeas, avocados, breadfruit, and papaya.

Among the tropical trees, flamboyant is one of the most beautiful. Its gorgeous firelike scarlet or purple flowers bloom from May to July. It grows readily from the dry sea-level areas of the south coast to the wet high areas of the mountain ranges. The maya, a barbed pineapplelike plant, often planted as a fence or as a boundary between small farms, thrives equally as well on the fairly strong "alkali"[6] soils as on the tropical rain-forest areas. The almendro is an ornamental deciduous tree which grows along most of the main highways. The nuts (Malabar almonds) ripen from July to August; they are edible. The hedionda is a low leguminous weed which seems to thrive throughout the island. Its seeds sometimes are mixed with coffee berries in preparing a hot beverage. It has not been long since the Australian pine was introduced, but it seems to be a tree as well adapted to the soils and climate of Puerto Rico as the maya. It is a fast-growing slender densely branched evergreen that is used as an ornamental tree along roadways and around houses, as well as a hedge which acts as a windbreak for fruit trees or other crops. It will grow on alkali land, if the concentration of salt is not much greater than 2

[6] The term "alkali" is used to indicate any harmful salt in the soil. Black alkali refers to sodium carbonate, and white alkali refers principally to sodium chloride.

percent, but none has been seen growing in the water-covered swamps. Many varieties of bamboo grow throughout the island. In the arid districts bamboo grows only along the edges of small ponds, and in the semiarid districts only along stream banks. Many of the bamboos are cut and used for fence posts, and some are used in the manufacture of furniture. The growing plant is used as a windbreak in some of the citrus groves, and it is also used on hillsides to help in the prevention of erosion. The commercial crops are discussed more fully under the section entitled "Agriculture."

Some plants are confined to rather narrow limits of environment, owing to the physical or chemical characteristics of the soil, to soil climate, or to elevation. Along the sandy beach, which fringes nearly the entire island, is a plant association consisting of matojo de playa, a low weedlike grass that migrates along the seaward side of the beach by means of rhizomes; yerba de sal, a prostrate fleshy red-stemmed plant tolerant to white alkali; and uva de playa which has broad leaves and an extensive root system. The height of the uva de playa

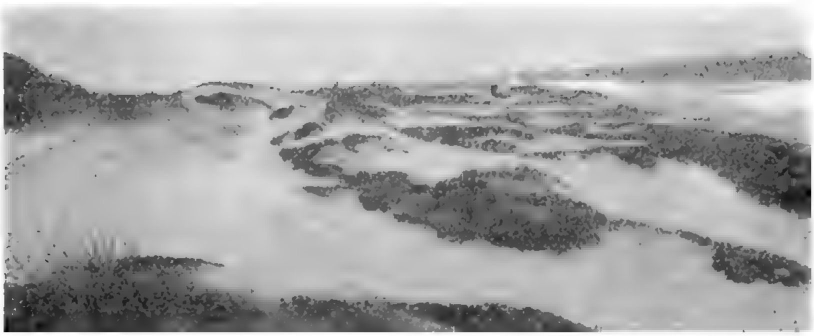

FIGURE 11.—Uva de playa and matojo de playa struggling desperately to stabilize the shifting sand dunes along the north coast.

Uva de playa y matojo de playa en lucha para estabilizar las dunas de la costa norte.

ranges from that of a nearly prostrate plant to that of a tall tree 8 inches in diameter. Generally, however, the plant is small, and its leaves are almost in contact with the soil. This helps to keep the sand moist and prevents the soil from blowing (fig. 11).

Closely associated with these drought-resistant sand-loving plant associations are plants that are resistant to salt water. In many places inland and parallel to the sandy coast are salt-water marshes and, in a few places, fresh-water swamps. The environment in these areas restricts vegetation to the water-loving or hydrophytic plants and alkali-resistant species. In some places the swamps extend to the quiet bays. In such places the plant nearest to the sea and that in the most salty water is the common mangrove, which has numerous strong aerial roots (fig. 12) that help to stop the agitation of the silt-laden water that pours into the swamps from the adjacent and faraway countryside. The silt and clay soon settle and thus build a mineral soil over the fast-decaying lower roots of the mangrove. Associated with the common mangrove but growing in areas having less concentration of salt, are the white mangrove, black mangrove,

and mangle botón. The last-named plant generally grows in dry climates and may be a considerable distance from the swamp, on alkali land. All the varieties of mangroves are important sources of wood for charcoal making. They quickly reestablish themselves and ordinarily are cut when 5 years old. At this age they produce from 15 to 20 cords of wood to the acre. Associated with the mangroves in wet open areas is a tall fern which grows to a height of 6 feet or more, and in many places the growth is so dense that it is impossible to penetrate it to any great distance. This fern is of little value, and it may crowd out stands of mangroves that have been cut over too frequently. Associated with this fern but now occurring in only a few places, such

FIGURE 12.—Mangrove with its characteristic stiltlike aerial roots.
Mangles, nótese las raíces aéreas.

as in the swamp a mile west of Humacao playa, is the palo de pollo tree, a tree very similar to the common mangrove except that each stump has many slender trunks and an exceptionally large buttress. This tree also is used as a source of wood for charcoal making. Malojillo grows in many of the more open spaces in association with the palo de pollo, indicating that there is little or no harmful salt in the soil.

On the south and east coast, as well as on the coasts of the small islands, inland from the mangrove swamps, are two plants which indicate the presence of salt, namely, barilla and verdolaga rosada. Both are low bushlike shrubs; the former has pale-yellow stems and the latter dark-green or reddish-brown thick leaves. These plants nearly everywhere indicate that the land has about 3 percent of white alkali within the topmost foot of soil. These plants grow on better drained soils than do mangroves. They may grow even on well-drained sand if there is sufficient spray from the sea to maintain a high content of salt in the soil. In many places they grow in clusters adjacent to but slightly higher than the barren areas very high in alkali (fig. 13).

Figure 13.—Salt flats near Parguera. Barren areas have in excess of 3 percent of sodium chloride; barilla in foreground is on soil containing from 2 to 3 percent of salt; the tuna brava, or pricklypear (left), is growing on soil containing about 1 percent of sodium chloride.

Llanos salados cerca de La Parguera. Los eriales tienen más de 3 por ciento de cloruro de sodio; barilla crece al frente en suelo que contiene de 2 a 3 por ciento de sal; la tuna brava, a la izquierda, crece en suelo que contiene como 1 por ciento de cloruro de sodio.

Figure 14.—Lignumvitae, or guayacán, trees, with a dense growth of Mexican bluegrass, or horquetilla morada. Note the effect of trade winds on the trees. Picture taken along the southern coast.

Árboles de guayacán o lignumvitae y horquetilla morada. Nótese el efecto del viento en los árboles. Fotografía tomada en la costa sur.

In general the salt content of the soil becomes less and less as the distance from the mangrove swamps increases, and the character of the vegetation changes accordingly. The most important plants a short distance from the mangrove associations are junquillo, a round-stemmed sedge, which nearly always grows on black-alkali land and

is therefore restricted to calcareous soils receiving a rainfall of less than 50 inches, and horquetilla morada (fig. 14), a fairly nutritious grass, which grows on both alkali and nonalkali land, as does the next important plant, Bermuda grass. These plants are associated on the wetter areas with junco de ciénaga, a tall coarse grass of little value. Cattail, sawgrass, caña de indio, and waterlily grow in brackish-water swamps in many parts of the island.

Associated with the Bermuda and horquetilla grasses in the arid sections are xerophytes, such as cacti and other drought-resistant plants (fig. 15). The most widely propagated cactus is the prickly-pear. It grows on Cabo Cabezas de San Juan near the Fajardo lighthouse, along the northwestern coast, and on Isla de Vieques (Island of Vieques), Isla de Culebra (Island of Culebra), and other dry islands, as well as in the large dry area extending from Guayama to the southwestern coast. In arid sections it grows on almost any soil, but in semiarid sections it grows either on very shallow permeable soils or on very sandy soils.

Figure 15.—Xerophytic vegetation on a steep limestone hill near Guánica quarry. Average annual rainfall about 30 inches.

Vegetación xerofítica en una colina caliza escarpada cerca de la cantera de Guánica. Promedia anual de lluvia—30 pulgadas.

Other cacti worthy of note are sebucán, or pitajaya, a many-branched bushlike wide-spreading cactus; sebucán, or dildo, a cactus shaped like a baseball bat; and the melón de costa which is nearly round (fig. 16). These cacti are numerous on the shallow soils of the limestone hills east of Faro Cabo Rojo to a point east of Ponce. They also grow on other hills in the semiarid sections, if they have not been removed in order to allow better grazing. Associated with the cacti are other thorny shrubs and small trees, such as escambrón colorado, tintillo, palo de burro, Santa María, mesquite, aroma casha, zarzarilla, and others. These are all of little value and are cut when the land is prepared for planting guinea grass, which is the most important pasture grass of the arid section. Several trees are more or less confined to the drier sections having calcareous soils. They are húcar (or úcar), algarrobo, tamarindo, almácigo, jagüey, lignumvitae, ceiba, and many species of acacia.

The húcar tree is confined to drier areas than are the other trees. It is used for building purposes, especially as sills, and also for fence posts. It is a gray-barked, spreading tree, often attaining a height of 30 feet. Many of these trees are nearly covered with Spanish-moss, especially in areas near Parguera and south of Baños de

Coamo. The algarrobo and tamarindo are conspicuous because of their dense spreading tops which make desirable shade for range cattle in the dry-land pastures. The tamarindo produces a substance around its podded seeds which is used in making a refreshing drink; it is also eaten raw or used as a dessert. The algarrobo produces a sausagelike pod which contains an ill-smelling but palatable substance that surrounds the seed. The almácigo is conspicuous by its shiny reddish-brown bark, wide open branches, and smooth limbs. It may grow in moist regions but is seldom seen in places where the annual rainfall is more than 65 inches. It is nearly valueless, even for charcoal.

FIGURE 16.—Melón de costa, or turkscap, growing on Ensenada clay, a shallow red soil derived from limestone. Annual rainfall about 25 inches.

Melón de costa, en Ensenada arcilloso, un suelo rojo poco profundo derivado de piedra caliza. Precipitación anual promedia alrededor de 25 pulgadas.

The jagüey, which has aerial twining roots, and the leguminous acacias have about the same climatic requirements as the almácigo; they grow in the eastern end of the island, in the northwestern part, on droughty soils in the more moist sections, and on the south coast. The lignumvitae at present is confined mostly to the drier parts of the island. It is a valuable and exceedingly hard wood. Unfortunately nearly all of these trees, as well as the other valuable trees, have been marketed, and few remain to propagate. The ceiba is common throughout the arid and semiarid sections. It is conspicuous, with its huge buttresses and sparsely branched giantlike trunk (fig. 17). The leguminous acacias are conspicuous along almost all the fence lines throughout the arid and semiarid sections. The air plant, with its ball-shaped matted structure, grows only in the arid or semiarid sections. It is prominent on many insulated wires, as well as on trees, cacti, and other vegetation of the south coast.

Inland from the arid or semiarid plant associations and below the rain forest, the vegetation consists for the most part of mesophytic plants or those that require a moist climate. This association includes the largest number of plants on the island, partly because there is a larger area involved. Growing within this area is the royal palm (fig. 18)—a magnificent symmetrical sentinellike palm that prefers

alkaline to acid soils but will grow on nearly every kind of soil, provided it has sufficient moisture. In some localities various parts of the royal palm are used. Its matured nutlike seeds (palmiche) are

FIGURE 17.—Giant ceiba tree growing on San Antón loam, one of the most productive soils in Puerto Rico. Sugarcane on this field produces from 70 to 90 tons an acre when the land is properly managed and irrigated.

Enorme ceiba en San Antón lómico, uno de los suelos más productivos de Puerto Rico. Este predio produce de 70 a 90 toneladas de caña de azúcar por acre, cuando se riega y se trabaja bien.

FIGURE 18.—The symmetrical royal palm that is used for many purposes.

La simétrica palma real se usa para muchas cosas.

nutritious and a favorite feed for hogs, as they contain nearly 6 percent of fat. Its bark is stripped off in long, narrow lengths (listones de la cortezas) and used as siding for the native houses. Its lustrous green leaves are used in the thatching of roofs or for covering coffee

seedbeds; some leaves are shredded and used in the making of chair seats. The racemes are used in the making of the locally used brooms. The leaf sheath, which is about 3 feet long and 20 inches wide, is used to cover roofs and walls, and it makes fairly good washtubs for the cleaning of clothes. The tigüero, or canoe-shaped palm sheath, is used as a convenient grain container, and, when the tree is cut, the cogollo, or bud, is used as a delicate salad which tastes very much like raw cabbage.

The llagrumo thrives in all moist areas and is very conspicuous on the abandoned coffee farms, on account of its ungainly stems and its large leaves, with white undersurfaces, floating in the breeze. It has a hollow fragile stem and is of very little value even for charcoal. The poma rosa, a bushlike tree which generally grows in moist acid soils, is used in basket weaving, for fence posts, for charcoal, and for roof tops for coffee seedbeds and nurseries. Its fruits are eaten by people and sometimes are fed to hogs. Associated with the mesophytic plants are many tropical fruit trees, such as jobo, corazón, guayaba, mabí, níspero, cacao, mamey, guanábana, citron, icaco, and cashew nut. The jobo is a deciduous tree that loses its leaves during winter, when it then presents a naked appearance, as all the limbs are nearly straight, smooth, and bare. It produces a plum-sized insipid yellow fruit during the summer and fall, which is relished by hogs and sometimes eaten by people. The corazón is a large tree having many branches, which, during the winter, produces heart-shaped grapefruit-sized solid reddish-colored slightly acid fruit. The guayaba, or guava, a semi-cultivated tree or bush, produces the pink-centered many-seeded walnut-sized fruit that is eaten raw or made into guava jelly or paste, some of which is exported to the United States. This bush becomes an obnoxious weed in many abandoned pastures. It readily develops a vigorous root system, and within 5 years, if not cut, an expenditure of about $5 an acre would be required to clear it from the fields. It grows on poor land nearly as well as on good land.

The mabí tree does not produce an edible fruit, but the bark is used in the preparation of a fermented drink. Sweetened water is added to an extract of the bark and allowed to ferment overnight. The níspero tree produces a fruit that is small, brown, sweet, and very high in sugar. It is relished by most people. The cacao tree was at one time important commercially, but at present a very small quantity of the seeds of the large ovate pods is gathered and prepared for market. The mamey is a dual-purpose tree; the thick smooth oblong leaves are used, especially in sandy soil, to protect young tender plants, such as tobacco, from the mole cricket, or changa. The fruit is sweet, yellow, and about the size of a coconut. The pulp is used raw, and some is made into a paste and consumed as a dessert. The guanábana produces a large somewhat pear-shaped fruit with soft rind, white fibrous pulp, and large black seeds; it is slightly acid; and the rind has many short fleshy spines. The fruit is eaten raw or as a dessert, and the pulp is made into drinks or sherbet. The citron grows in only a few groves, but it seems to be capable of producing a profitable commercial crop and in time probably will occupy a larger acreage than at present. Its requirements for soil and climatic conditions are similar to those of the grapefruit tree. The fruit is used in making candy. The icaco is a bushlike tree producing black, white, or purple plumlike fruit which has a large dark seed and a small quantity of sweet white

pulp that is eaten raw. This bush will thrive on droughty unproductive soils. The cashew tree grows in semiarid sections on droughty soil as well as within mesophytic plant associations. The nut is kidney-shaped and about one-fourth inch thick. The roasted kernel of the seed is of good quality and delicious, but it is seldom sold on a commercial scale. The pulp of the sour fruit is sometimes cooked for dessert. Some of the other associated forest trees are higüero, llume palm, cupey, jácana, bay rum tree, búcare, African tuliptree, many kinds of robles, moca, guamá, and guaba. The last three are used extensively as shade trees on the coffee plantations. The higüero produces a large oval gourdlike fruit (calabash) that is picked, dried, seeded, and used locally for water containers and cups. The llume palm presents an interesting sight when its tall thin cylindrical trunk and large pinnate leaves are fanned by the breeze. This palm prefers alkaline soils, and it grows only in the rugged limestone hills and in the rough land of Isla de Vieques. The cupey tree is conspicuous in the limestone section, as its long aerial roots resembling black ropes, swing far down over the cliffs. This tree usually grows as a parasite on other trees until its aerial roots become anchored in the soil. The jácana is a hardwood and is used for building purposes. The bay rum tree grows in moist as well as in semiarid sections. Its leaves are often gathered, brewed, and distilled, and the product is sold for making bay rum. The búcare, African tuliptree, and roble have striking blossoms which give the landscape added attraction. The leaves of the búcare, especially of the dwarf variety, make nutritious forage for livestock. The leaves, which are very high in protein, may be fed green or may be ground. This tree is used also as a support for the climbing vanilla plants.

The more common small plants in the moist sections are the many common ferns, sensitiveplant, fresa, and cohitre morado. The common ferns are very abundant along road banks and on idle land. Some species are very good indicators of strongly acid soil, low in plant nutrients. Ferns also extend into the rain-forest plant association. The sensitiveplant grows in many pastures and on many plantations. It is regarded as a weed. The fresas are more abundant at elevations of more than 1,500 feet than at the lower levels. The fresa berries are similar to raspberries, and they ripen throughout most of the year. They are gathered, and many of them are sold locally from the roadside. They are eaten fresh and used as dessert. Cohitre is similar to wandering-jew. Some varieties are used for hog feed. The cohitre morado is effective on the densely shaded coffee farms as a soil binder, thus helping in the control of erosion.

The most important grasses growing in the moist-climate areas are matojo, cerrillo, and St. Augustine grass. Matojo is a rank-growing bunchgrass that is eaten by livestock, but it seems to be low in nutritious constituents. The mountain matojo is used in thatching some of the bohíos, or mountain houses (fig. 19). Cerrillo ranks as a fair grass for livestock. It grows on many kinds of well-drained soils throughout the moist and semiarid sections. St. Augustine grass is considered the best upland grass. It not only is very nutritious, but it is one of the best plants for the control of erosion on the island, as it readily forms a thick mat and its long rhizome-stemmed foliage creeps over banks and over the sides of gullies, thereby helping to hold the soil in erodible places. It is used also on lawns.

As the rainfall increases there is a gradual change from the moist-climate plant association to the rain-forest vegetation, and thence to the moss vegetation of the areas having the highest rainfall, which are

FIGURE 19.—A bohío, or mountain home. Generally some subsistence crops, such as bananas, beans, yautias, yuca, pigeonpeas, and sweetpotatoes, are planted in the dooryard or nearby.

Un bohío. En general se encuentra algunos cultivos como guineos, habichuelas, yautías, yuca, gandules y batatas alrededor de la casa.

FIGURE 20.—Dense vegetation in the rain forest—treeferns, mountain palms, bananas, and many other plants—all striving for existence.

Exhuberante vegetación en un bosque—helechos arborescentes, palmas de sierra, guineos y muchas otras plantas.

the high wind-swept cool fog-laden peaks. Some of the most important plants of the rain-forest vegetation are (figs. 3 and 20) palma de sierra, or mountain palm, treefern, tabonuco, granadillo, sabino,

maricao, mahogany, and Spanish cedar. The mountain palm is similar to the royal palm, but it does not have so symmetrical an appearance and is more slender. It is used to some extent in building, the trunk being split into narrow strips for siding. The treefern is of value only in helping to prevent erosion, as it has a good root system and its leaves help to break the force of the rain. The tabonuco tree is valuable for its timber, and its resin is sometimes used in making torches. The granadillo, sabino, and maricao are used for building purposes. The mahogany and Spanish cedar are valuable woods for cabinetmaking. Neither tree is attacked by termites. Both grow in the moist sections as well as in the rain forest.

The moss association is confined mostly to the high peaks of the Sierra de Luquillo, where the precipitation is heavier than elsewhere on the island. The most common trees of this mossy plant association are roble de sierra and granadillo. On the high wind-swept peaks the trees, although mostly virgin, have a dwarfed appearance. They gradually increase in size with decreasing elevation. Those growing on the summits of the highest peaks range from 2 to 6 feet in height, but at the lower elevations they may attain a height of 30 feet. At the high elevations the branches are crooked and are so dense and interlaced that only a small amount of sunlight penetrates to the moss and sedge-covered shallow and nearly saturated rocky soil below. Many species of mosses and ferns are abundant. Most of the mosses grow on the branches of dead trees and on rocks. The bejuco de palma and bejuco de rana, two clinging vines, are abundant in moist climates and in the areas of highest rainfall. Orchidlike plants are conspicuous on the tree trunks in the high elevations and in the lower part of the rain forest. Many other plants grow throughout Puerto Rico, such as ornamental shrubs and flowers. Although many of them are very beautiful, most of them lack pleasing fragrance. Mushrooms and toadstools are rarely seen anywhere.

A valuable descriptive account of the plant ecology and plant distribution in Puerto Rico is given by Cook and Gleason (*12*).

ANIMAL LIFE

According to Danforth (*14, p. 18*), Puerto Rico does not have any indigenous land mammals; squirrels, skunks, minks, coyotes, alligators, or similar animals do not inhabit any part of the island. The most common animal is the mongoose (*Herpestes birmanicus*), which was imported from Cuba in 1877 for the purpose of destroying rats and snakes. The rats have not been controlled, there never were many snakes, and now the mongooses have increased so rapidly that they have become a nuisance. They inhabit all parts of the island and are destructive to chickens, lizards, and ground-nesting birds. Roof rats, house rats, and house mice are fairly numerous, especially in the congested parts of towns. The rats do considerable damage to sugarcane stalks and coconuts. Many of the coconut groves are protected with a 10- or 12-inch metal band placed around each palm at a height ranging from 4 to 8 feet above the ground (fig. 25). Bubonic plague, which is spread to human beings from infected rats, has appeared twice in San Juan and nearby cities.

Lizards are both prevalent and beneficial. They range in size from the 15- or 20-inch lagarto (*Ameiva exul*) to the 3-inch lagartija

(*Anolis poncemesis*). All the lizards are insectivorous and do incalculable good by destroying millions of flies, mosquitoes, and other insects. The lizards run about at will from the houses to the fields in all parts of the island. Several kinds of frogs have been imported and may be found in the wet areas adjacent to the coast as well as in the tropical rain-forest areas. The importation of the toad (*Bufo marinus*) has been one of the greatest benefits to the south-coast cane growers, as the toads have multiplied rapidly and have the white grub nearly under control by eating the May beetle (*Lachnosterna portoricensis*), the adult of the white grub.

Birds are not so plentiful as might be expected, owing in part to the destruction of the nests and young birds by hurricanes and in part to the density of the population, as boys and young men destroy the eggs and kill the birds. The greatest number of birds seem to be in the most sparsely populated areas, such as the arid southwest. Some of the most conspicuous birds (*14*) are the reinita, or Puerto Rican honey creeper; the mozambique, or grackle, that follows plows, catching grubs and other insects; the gorrión, or carib grassquit; the ruiseñor, or mockingbird; the pitirre, or gray kingbird; the golondrina, or barn swallow; the putilla, or killdeer; and the aura, or southern turkey vulture. Several species of doves and ducks are hunted and are relished by sportsmen. Herons are very numerous in the lagoons and mangrove thickets.

Bats are fairly numerous in the caves of the limestone section, especially on Mona Island. Bat guano is used as a fertilizer, but the quantity obtained now is much less than formerly.

There are many crabs along the coast. The most conspicuous are the large blue land crabs, or cangrejos (*Cardisoma quanhumi*), which are very numerous along the wet poorly drained coastal lowland soils. After the first few rains following a long dry season, thousands of crabs are caught and eaten by the people. These crabs do considerable damage to sugarcane, and poisoned bran must be placed near their holes in order to reduce their number as much as possible.

More than 1,400 different species of insects (*50*) have been identified on the island. These include many that are destructive to crops, such as the changa, or mole cricket (*Scapteriscus vicinus*), which does much damage in loose sandy soils, especially on level coastal plains, to the young tender crops, such as tobacco and minor crops; the white grub which causes much loss in the sugarcane fields on alluvial lands; the giant rhinoceros beetle, which attacks and kills young coconut palms; the sugarcane rhinoceros beetle, which at times feeds on sugarcane; the coffee-leaf miner, a small caterpillar that is very destructive to the coffee leaves; and the hormiguilla, a small ant that makes tunnels in living trees, especially the guamá one of the best shade trees for coffee. The damage caused by the pink bollworm has been one of the reasons for the small acreage devoted to cotton. The West India fruitfly has been a serious handicap to the fruit grower. Flea beetles do much damage to the tobacco plants in areas receiving less than 65 inches of annual rainfall. The corn earworm is a serious pest in both sweet corn and field corn.

Other important insects are the various species of termites, the polilla being very destructive to buildings of imported lumber. The comejen's large black "niggerhead" nest is very conspicuous on fence posts, trees, and even on the ground throughout the island. The

termite has social habits similar to the bee; its brittle vesicular nest, 1 foot or more in diameter, contains workers, soldiers, and a single royal pair.

Flies are not so numerous as might be expected, and very few enter the houses, although the windows and doors are usually open during the day. Mosquitoes are seldom seen during the daytime, except in a few swamps, but they are very numerous at night, and certain parts of the lowlands are infested with a fairly high proportion of malaria-carrying mosquitoes.

The number of deaths from malaria has decreased rapidly, owing to the work of the Department of Health of Puerto Rico and to the drainage work and studies on malaria by the Rockefeller Foundation.

Bees are not so common as might be expected. According to the 1935 census of the Puerto Rico Reconstruction Administration (*34*), 19,160 colonies were reported from 1,466 farms. The largest numbers of apiaries are in the mountainous sections, especially in the coffee districts. The exportation of honey during 1938–39 was 1,115,785 pounds, valued at $42,272, according to the Annual Book on Statistics of the Puerto Rico Department of Agriculture and Commerce.

The principal parasites affecting livestock are ticks, lice, flukes, tapeworms, and roundworms. The ticks and tick fever caused by the microparasites do incalculable damage to livestock. The loss of life is not great, but the vitality is sapped from the animals. A systematic tick-eradication program is now under way. Lice are prevalent among all animals in all parts of the island. Flukes are particularly obnoxious in the arid sections and in areas of calcareous or neutral soils, as their host, the snail (*Lymnaea cubensis*) (*48, p. 18*), is more prevalent on alkaline than on acid soils. The most favorable location for the snail is in wet or moist lowlands where the soils are neutral or calcareous. The flukes enter the livers of both man and beast. Tapeworms and roundworms are very common and serious parasites in many sections.

Visible effects of microfauna activity are noticed throughout all the soils. There seems to be more earthworm activity in the humid sections than in the nonirrigated arid or semiarid sections. The surface soils of the irrigated lands contain an abundance of worm casts, indicating the activity of numerous worms. However, the casts are not so plentiful as in the upland soils in the humid sections, especially in the Cialitos, Catalina, and related soils. The principal visible microfaunas are termites, white grubs, ants, fishworms, and nematodes, all of which play a very important role in mixing the plant residues and mineral part of the soil as it passes through their bodies.

The aquatic animal life in the waters near the coast, in the mangrove swamps, and in fresh-water streams includes fish, oysters, lobsters, corals, many kinds of mullusks, and sponges, The principal fish are el pargo, or lane snapper; macarela española, or Spanish mackerel; pargo rojo, or red snapper; el arenque, or herring; pámpano, or pompano; and salmonete blanco, or white mullet, of the salt-water and el dajao of the fresh-water streams. A large number of people make their living by seining fish along the coast. At times they catch barracuda, sharks, and manatees (or sea cows) in their nets.

The oysters are small and are gathered, not from beds but from the numerous mangrove roots. The lobsters are fairly numerous and are delicious. The principal corals along the beach are the fan

and brain corals. Many kinds of edible mollusks are gathered and eaten by the coast dwellers. The sponge most commonly seen is the finger sponge. Neither the sponge nor the mollusk industry is very important.

Domestic animals are discussed in the section on Agriculture.

POPULATION

Puerto Rico was discovered and named by Christopher Columbus in November 1493, or 127 years before the landing of the Pilgrims at Plymouth Rock. At that time the inhabitants were Indians, who have since disappeared. Puerto Rico remained Spanish territory until it was ceded to the United States by Spain in 1898. The present political status is that of a territory with certain legal limitations. The island is divided for governmental purposes into 77 municipal districts,[7] and these again into barrios.[8] The present inhabitants are for the most part either descendants of Spanish settlers or of Negroes brought in for work on the plantations. They are American citizens and have a right to vote at elections on the island and for Federal officials when residing in the United States.

According to the Federal census, the total population in 1930 was 1,543,913, or 454 people to the square mile. Of this number, in addition to the native-born Puerto Ricans, 3,585 were born in Spain, 2,160 in the United States, 367 in Central America and South America, 342 in France, and a few in other countries. Preliminary data of the 1940 census show an increase of 21.1 percent, to a total of 1,869,245, or 549.7 people to the square mile. The density of the population, which varies greatly from place to place, creates the most serious social and economic problems confronting the insular government. Few people build their homes on the good alluvial lands paralleling the larger streams, on the forest-covered soils of the high elevations, or on the pasture lands of the south coast.

The most densely populated parts of rural Puerto Rico (fig. 21) are on the shallow brown hill-land soils near Trujillo Alto and Rincón and south of Cabo Rojo, also from Hatillo (Hatillo) to Aguadilla on the soils derived from limestone (fig. 22), and on the soils along the north coast. In these areas there are more than 600 people to the square mile. This is a very grave situation, because most of the people depend almost entirely on agriculture for their support. A high proportion of the area of Puerto Rico consists of shallow, stony, steep, or submarginal land, and it is doubtful whether agriculture can support such a dense population and give the people a reasonable standard of living. Many people obtain part-time work in sugar centrals, tobacco-stripping shops, needlework shops, and other industries; but, even with this additional income, families are able to obtain only the bare necessities of life. Thousands of people of all ages are undernourished.

The large population has had its effect on the natural resources of the island, such as forests, soils, and fish. The great increase in population, which began more than 100 years ago, naturally has led to the removal of forests and the planting of both subsistence and major crops. Most of the timber has either been sold or is rapidly being

[7] The municipal district, or municipality, is an unsurveyed but somewhat definite land area averaging 44.6 square miles, or slightly larger than a township.

[8] The barrios are unsurveyed but fairly well recognized land areas about one-tenth the size of a municipality, or about 4 square miles.

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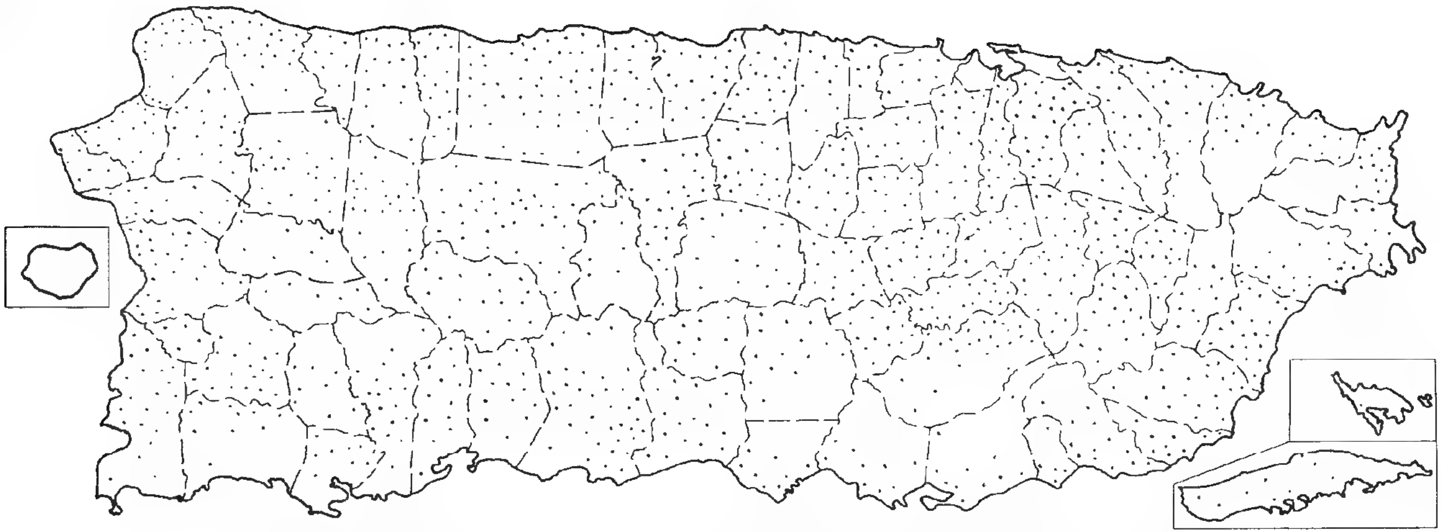

FIGURE 21.—Distribution of rural population in 1935. Each dot represents 1,000 people.
Distribución de la población rural en 1935. Cada punto representa 1,000 personas.

FIGURE 22. Aerial photograph of about 600 acres in the irrigated district near Isabela. Approximately 800 people live in the 150 or more houses seen in this picture. Most of the soils are deep permeable red or yellowish-red Matanzas and Coto clays which are fairly well adapted to nearly every crop grown on the island. (Photograph taken by U. S. Navy.)

Fotografía aérea de cerca de 600 acres en el distrito de riego de Isabela. Aproximadamente 800 personas viven en las 150 ó más casas que se ven en la fotografía. Muchos de los suelos son arcillas Matanzas y Coto, profundas, rojas o amarillo rojizas y permeables y son bastante adaptables a casi cualquier cultivo de la isla. (Fotografía tomada por la Marina de los EE. UU.)

used for the making of charcoal, and this exploitation of the forest resources over a long period of years has nearly depleted the timber. According to Gill (*19, p. 133*), "probably 50 percent of Puerto Rico, or 1,000,000 acres, may be classified as true forest soil, but of all this only 110,000 acres still remains uncut. Eighty percent has been devastated." One reason so much of the land has been cut over is because the cutting has been unrestricted, with no provision made for reforestation. Fires never have and probably never will be a menace to either the forest or grass. A comprehensive and intensive forest program is needed immediately to make Puerto Rico self-supporting in wood requirements. Rapid progress in this direction has been made during the last 2 years, owing to activities of both the Federal and insular governments. At present (1940) about 186,155 acres are in forest, of which 26,010 acres are in the Federal forest reserve (Caribbean National Forest) and 40,000 acres are in insular forest land. The largest areas include some of each of the following: The rough, rugged mountainous areas, the mangrove swamps, and the shallow soils derived from serpentine and limestone in humid and arid regions, respectively.

The pressure of the increasing population forces the people to cultivate steeper and steeper land and a greater and greater acreage to the person, because returns to the acre are becoming less. With the exception of the soils of the alluvial lands, most of the cultivated land in humid Puerto Rico has been leached to such an extent that a deficiency of calcium, phosphorus, and magnesium seems to exist. A very low percentage of the owners of small farms [9] use fertilizer or manure to offset the loss of these necessary mineral elements. The plants produced, whether grain plants or grasses, do not have the maximum food value for the development of bones, teeth, and the physical well-being of the animals and people. Rickets, poor teeth, and poor health are common among some of the natives in the humid districts.

Livestock that have been grazed on grasses of the alkaline and semiarid districts have larger bone development, smoother hair, and better general appearance than those pastured in the moist mountainous districts where acid leached soils are dominant and the grass is tall and dense.

Sheet erosion has been reducing crop yields year after year on improperly used hill land (fig. 23). The combined destructive effects of leaching and erosion, in addition to the constantly increasing population, make an acute problem in land utilization. Probably one of the most effective measures for better land use is through the Puerto Rico Extension Service in directing the jibaros,[10] through their conuco [11] agriculture, to plant more strip crops with the contour of their land. Increasing quantities of fertilizer and lime must be used each year to restore the fertility that is lost by cropping and erosion, in order to increase or maintain the same yearly production of agricultural crops.

Few of the fresh-water fish become large before they are caught and used for food, and the only wild game left includes a few doves and ducks. Neither fish nor game is protected by strict game laws.

[9] According to the 1935 census of the Puerto Rico Reconstruction Administration (*34*), 27.9 percent of the improved land was in farms less than 50 acres in size.
[10] Jibaros refer to the tillers of small patches of land.
[11] Conuco agriculture refers to garden farming of small patches of several kinds of minor crops, such as pigeonpeas, beans, corn, yautia, yuca, bananas, and others.

Within the last few years the insular forest service has been stocking some of the streams with suitable kinds of fish. This should prove beneficial, but, owing to the large numbers of people, game laws cannot be made very effective, and it is doubtful whether fish or game ever will be very plentiful.

FIGURE 23.—Severe erosion on an improperly farmed hillside of Descalabrado silty clay, eroded phase, where the annual rainfall is sufficient to encourage the planting of crops, yet is not sufficient for the plants to make rapid growth which would check the force of tropical showers. The gardens to the right are properly farmed.

Fuerte erosión en una ladera de Descalabrado limo-arcilloso, fase erosiva, mal trabajada. La lluvia anual en este sitio es suficiente para la siembra de cultivos, pero no lo bastante para que las plantas crezcan rápidamente, y sirvan de resistencia a la fuerza de las lluvias tropicales. Los huertos hacia la derecha están bien trabajados.

TOWNS

San Juan, the capital and largest city, is on the north coast in the east-central part of the island. It is the location of the United States Army and Navy radio stations; other Army stations are at Borinquen

(near Aquadilla), near Vega Baja, and at Cayey. In 1940 the population of San Juan was 169,247. The business section and a part of the residential section are on an island connected to the mainland by bridges. Ponce, which is located near the center of the south coast, is the second largest city, with a population of 65,182 in 1940. Mayagüez, which is centrally located on the west coast, is the third city, with a population of 50,376 in 1940. Caguas, the fourth largest city, had a population of 24,377. It is situated in a mountain valley about 35 kilometers south of San Juan. The populations, elevation above sea level, approximate location, and principal crops and industries of the cities and larger towns are given in table 2.

TABLE 2.—*Data regarding principal cities and towns in Puerto Rico*

City or town	Population [1]		Increase or decrease in population	Elevation above sea level	Location	Principal crops and industries
	1940	1930				
San Juan	169, 247	114, 715	47. 5	[2] 24. 7	Northern coast	Commercial.
Ponce	65, 182	53, 430	22. 0	[2] 51. 5	Southern coast	Commercial, sugarcane.
Mayagüez	50, 376	37, 060	35. 9	[2] 7. 3	Western coast	Needlework, coffee, sugarcane.
Caguas	24, 377	19, 791	23. 2	[3] 232. 9	Mountain valley	Tobacco, sugarcane, subsistence crops.
Arecibo	22, 134	12, 863	([4])	[2] 27. 3	Northern coast	Sugarcane, grapefruit, commercial, subsistence crops.
Río Piedras	19, 935	13, 408	48. 7	[3] 78. 7	do	Sugarcane, fruits.
Guayama	16, 913	10, 953	54. 4	[2] 244. 5	Southern coast	Sugarcane, livestock.
Bayamón	14, 596	12, 986	12. 4	[2] 53. 7	Northern coast	Sugarcane, grapefruit, pineapples.
Aguadilla	13, 468	10, 952	23. 0	[2] 13. 9	Western coast	Sugar cane, coconuts, commercial, needlework.
Yauco	9, 985	8, 607	16. 0	[2] 104. 1	Southern slope	Sugarcane, coffee, livestock.
Coamo	8, 691	5, 831	49. 0	[3] 354. 3	Southern valley	Livestock.
Cataño	7, 924	7, 044	12. 5	[5] 20. 0	Northern coast	Commercial.
Humacao	7, 624	7, 937	[6] −3. 9	[3] 52. 5	Eastern coast	Sugarcane.
Fajardo	7, 108	7, 322	[6] 2. 9	[3] 32. 8	do	Do.
Manatí	6, 771	7, 449	[6] −9. 1	[2] 91. 2	Northern coast	Sugarcane, fruits.
San Germán	6, 446	5, 636	14. 4	[5] 244. 3	Southern valley	Sugarcane, coffee, subsistence crops.
Cayey	5, 622	5, 953	[6] −5. 6	[5] 1,300.0	Mountain valley	Tobacco, subsistence crops.
Vega Baja	5, 409	4, 784	13. 1	[2] 28. 9	Northern coast	Sugarcane, fruits.
Carolina	5, 368	4, 454	20. 5	[3] 39. 3	do	Sugarcane, subsistence crops.
Cabo Rojo	5, 303	4, 605	([7])	[2] 52. 3	Western valley	Do.
San Lorenzo	5, 181	4, 916	5. 4	[5] 200. 0	Interior plain	Tobacco, sugarcane, subsistence crops.
Juncos	5, 009	5, 297	[6] −5. 4	[3] 446. 0	do	Sugarcane, tobacco, subsistence crops.
Sabana Grande	4, 783	3, 778	26. 6	[5] 289. 0	Southern valley	Sugarcane.
Yabucoa	4, 542	3, 841	18. 3	[3] 52. 5	Eastern coast	Do.
Utuado	4, 430	4, 758	[6] −6. 9	[2] 442. 6	Mountain valley	Coffee, tobacco, subsistence crops.

[1] Population data from the United States census.
[2] Elevations from U. S. Geological Survey.
[3] Barometric elevations by insular department of interior.
[4] Barrios Buenos Aires, Miramar, and San Luis were annexed to Arecibo town in 1937. The figure for 1930 is not, therefore, comparable with that for 1940.
[5] Approximate elevation.
[6] Minus sign indicates decrease.
[7] Pueblo Nuevo was organized from part of Miradero and annexed to Cabo Rojo town in 1932. The figure for 1930 is not, therefore, comparable with that for 1940.

Most of the larger cities are near the coast and adjacent to land that is well adapted to the production of sugarcane. Most of the inland mountain towns are small and generally have but one improved road leading to and from the town (fig. 24).

FIGURE 24.—The small inland town of Pueblito del Río which has but one automobile road and one oxcart road. Sugarcane is grown both on the alluvial lands and on the sloping hills.

Pueblito del Río, solamente tiene una carretera para automóviles y un camino para carretas. La caña se siembra en las tierras de aluvión y en las colinas.

TRANSPORTATION

Among the United States ports from which goods may be shipped to Puerto Rico are New York, Baltimore, New Orleans, Mobile, Tampa, Galveston, Houston, and San Francisco. Boats from other countries stop in San Juan harbor at frequent intervals. Ponce, Mayagüez, Aguirre, Fajardo, Arecibo, and other seacoast towns also have harbors where freighters pick up exports and leave imports. Passenger boats stop at Ponce, Mayagüez, and, at times, at some other ports. San Juan has connections with the United States by regular boat and airplane transportation, also by cable and telephone.

According to the Annual Book on Statistics for 1938–39, 22,607 motor cars are registered, of which 12,608 touring cars, 2,287 light trucks, and 2,073 heavy trucks, a total of 16,968 vehicles, are privately owned. There were 4,327 touring cars, 38 light trucks and 1,274 heavy trucks, or a total of 5,639 vehicles, under public ownership. This represents about 1 car for every 83 persons. Very few horse-drawn buggies and carriages are seen, and only a very small proportion of the rural inhabitants have saddle horses. Walking is the principal means of travel by day laborers and their families. Pedestrians throng the highways throughout the day and most of the night.

Lines of the American Railroad Co. of Porto Rico and other companies, subsidiaries of sugar mills, such as the Fajardo Development Co., or the Ferrocarriles del Este (Eastern Railroad), Fortuna Railroad Co., and Ponce & Guayama Railroad connect nearly all the coast towns, except those in the southeastern part of the island, from Arroyo to Yabucoa. Most of the lines have single tracks and are 1 meter wide. Owing to the rough terrain, the railroads do not cross the interior. They carry first- and second-class passengers, freight, and express, but most people travel by either bus or public cars, which ply between all towns, picking up and discharging passengers at any place along the road. The fare is about 1 cent a kilometer. All sugar centrals have a network of railroads throughout their holdings. Most of the railroads are very narrow gaged, and some of the tracks are removed

as soon as the crop is taken off the land. The towns and sugar centrals are connected by telephone and telegraph, but very few rural residences have telephones or free delivery of mail. During warnings

FIGURE 25.—A 15-foot highway along the coast. Note the metal bands on the coconut palms to keep the rats from climbing them.

Carretera de 15 pies de ancho a lo largo de la costa. Nótese las bandas metálicas en las palmas de coco para evitar que las ratas suban a las palmas.

of an approaching hurricane, news spreads surprisingly fast by verbal communication.

Hard-surfaced roads, or carreteras,[12] connect all the towns. Many of the secondary roads, or caminos, leading into the mountains or hilly country are impassable except by oxcart, saddle horse, or on foot. Thousands of the country homes, or bohíos, are reached only

[12] In Puerto Rico carretera is used to designate a hard-surfaced main-traveled automobile road; a callejón refers to an oxcart road, especially in the sugarcane fields; a camino refers to a second-class road; and a vereda refers to a footpath.

by foot and horse trails, which penetrate to all parts of the island. The trails zigzag up the steep rocky mountainsides then generally follow the ridge tops. The pack animals carrying coffee, tobacco, charcoal, bananas, and other crops on their way to towns, and returning with rice, beans, canned fish, and other provisions, have great difficulty in carrying comparatively light burdens through mud ankle deep or over the steep rock-strewn mountain slopes. Transportation in the mountainous districts is slow and expensive. Most of the first-class roads have the hard limestone as a base and a top dressing of tar, and, as there is no freezing or thawing to heave the underlying soil, the roads last for a number of years. Most of the roads, however, are only 15 feet wide (fig. 25), and, as a high percentage of all merchandise and products is moved with large trucks, they soon become uneven and require continual maintenance. Many of the secondary roads are made from crushed soft limestone which is soon worn away by the tropical downpours. On the large holdings of the sugar centrals, roads are numerous, and generally there is an oxcart road (callejón), around every 10 or 20 acres. Only the most important callejones are shown on the soil survey map, and many of the trails (veredas) are not shown.

EDUCATION

Every community has some public schools, but most of the isolated rural districts are very much handicapped by inadequate schools, both as regards number and size. Most of the schools in these districts have only four grades. In most of them the first-grade pupils attend for one-half of the day and the second-, third-, and fourth-grade pupils for the other half. Each teacher has about 60 children during the day. The 1935 census of the Puerto Rico Reconstruction Administration (*34*) shows that the average number of persons in a family is 5.4. Of the children between the ages of 7 and 13 years, 61.7 percent attend school, and of those between the ages of 14 and 15 years, 40.7 percent attend school. The census figures show that 35.1 percent of the people over 10 years old are illiterate.

The 54 districts that have established second-unit schools are very fortunate, as the schools under this system equal or are superior to schools in the United States, especially in regard to local needs, for instance, educating the children's taste for beneficial vegetables not commonly used by the families but which can be and are grown by the boys of the school on the 4- to 25-acre tracts of school land. Several teachers are employed at each of these rural schools. Domestic science, agriculture, manual training, and ceramics are some of the subjects taught besides the regular graded-school studies.

Spanish is the language of the people, but English is understood and spoken by all high-school students and many pupils in the graded schools. The University of Puerto Rico is located in Río Piedras. The enrollment for 1936–37 (first semester) was 4,306 students, of whom 1,492 were men and 2,814 women. The School of Tropical Medicine is in San Juan. The College of Agriculture and Mechanic Arts is near Mayagüez, where the enrollment in agriculture is about 200 and in engineering about 300 students. The Polytechnic Institute is at San Germán, and there are several denominational schools on the island.

Most of the municipalities have a county agricultural agent, and at present there are nine agricultural extension demonstrations farms,

locally called granjas. The average size is about 16 cuerdas.[13] The Agricultural Experiment Station of the University of Puerto Rico, having 185 cuerdas for agricultural purposes, is located near Río Piedras, and the irrigation substation, located west of Isabela, covers a total of 80 cuerdas in 3 farms on different soil types. The Federal Experiment Station has a total of 410 cuerdas in 2 separate farms and is located near Mayagüez. Valuable information in agriculture is obtained from all these stations and farms.

Every town has at least one church, which generally joins the plaza on the east, and a few churches have been built in the rural districts. As a rule, each town has only one cemetery, and there are very few in the rural districts. Less than 500 cuerdas are occupied by cemeteries in Puerto Rico. Several daily newspapers are published in San Juan and one or two in Ponce and Mayagüez. The papers are printed in the Spanish language, with the exception of one or two that have an English supplement. There are also several magazines published on the island, one of which is a scientific agricultural magazine. San Juan has two radio broadcasting stations, and broadcasting programs are heard from both Europe and the United States. The larger cities have public libraries, and nearly every town has a municipal hospital. San Juan has many clinics and hospitals and one Young Men's Christian Association building, the only one on the island.

WATER SUPPLY

In many places, especially in the rural districts, the water supply is insanitary and inadequate. In the northwestern part of the island, in the limestone area, underground drainage forces the people to use water caught in mudholes and depressions, especially after the limited supply of rain water caught from the eaves of the metal-roofed houses has been used. In irrigated districts the people use irrigation water. In the mountain areas any stream or spring water is used, regardless of its state of sanitation. The quality and quantity of water varies considerably from place to place. Probably the best water comes from springs originating in the serpentine rocks, such as those east of Mayagüez on Las Mesas. Within areas where granite rocks are dominant, surface water for drinking purposes is scarce during the dry seasons, and throughout all limestone areas most of the domestic water is obtained from the eaves of the metal-roofed houses. In areas where the dominant rocks are tuff and shale, the water supply is fairly good and usually abundant. Municipal water hydrants are located along many of the roads in the thickly populated rural districts where natural water is scarce. Most of the household water is carried in 5-gallon cans by the women, and often the water supply is from one-eighth to one-fourth of a mile down the mountainside from the house. Practically the only windmills or pumps in use are in pastures in the arid and semiarid districts. These wells provide water for people and for livestock. Water for the towns generally is piped from mountain streams through aqueducts, and in the larger cities it is chemically filtered with aluminum sulfate and treated with chlorine, but in the smaller towns it is filtered by settling and is treated only with chlorine. Typhoid fever and other water-borne diseases are disseminated by the insanitary water supply. Most of the household washing is done along the stream banks (fig. 26).

[13] A cuerda is equivalent to 0.9712 acre, or 42,305 square feet.

According to the data of the commissioner of health of Puerto Rico for 1937, the death rate per 100,000 population from diarrhea and enteritis was 482.4 people; from tuberculosis, 287.1; from pneumonia,

FIGURE 26.—Washing clothes along one of the shallow streams.
Lavando ropa en una quebrada.

187.8; and from malaria, 129.5. These five diseases accounted for 1,086.8 deaths per 100,000 out of a total death rate of 2,094.

FARM BUILDINGS

Many of the dwellings, or bohíos, are small and flimsy. Some are constructed with palms (fig. 19), either the leaves or sections of the outer trunk, and many are built from boxes and scraps of metal

FIGURE 27.—A hurricane shelter which could accommodate from 10 to 15 people, and a thatch-roofed house in right background.
Una tormentera para 10 ó 15 personas y una casa techada de yaguas a la derecha.

roofing. In general the dwelling has one or two rooms, with a lean-to for cooking. These homes afford only the bare necessities. The more well-to-do landowners have modern homes substantially built to withstand hurricanes, but at times even these are destroyed. Among the smaller dwellings there are a few hurricane shelters (fig. 27), but ex-

FIGURE 28.—Modern sugar central where both raw and refined sugar are manufactured. In the right foreground sugarcane is being loaded on oxcarts. Light streaks in sugarcane indicate areas of soil very high in lime, which condition causes chlorosis in the cane. Level soils are mostly Mercedita clay. Hills in background are used only for pasture.

Moderna central azucarera donde se fabrica azúcar cruda y refinada. A la derecha se carga azúcar en carretas. Los sitios claros en la caña indican áreas de alto contenido en cal, lo que causa clorosis en la caña. Los suelos llanos son principalmente Mercedita arcilloso. Los cerros al fondo se usan solamente para pasto.

perience has taught that their numbers are far too few to care for all the people during a storm.

The sugar centrals have many more modern buildings and equipment, the valuation of which ranges between $2,000,000 and $3,000,000 for the larger centrals (fig. 28). They have their own stores (tiendas), warehouses (almacén), and hospitals. The grapefruit growers have

Figure 29.—Typical coffee finca. The concrete floors are glacis for drying the coffee. Building to right is the warehouse. The plants in the foreground are yautias.

Finca de café típica. Los pisos de concreto son glacis para secar café. El almacén está a la derecha. Yautías al frente.

Figure 30.—Open-sided modern dairy barn.

Lechería moderna.

modern American homes, and many have a grading shed and possibly a packing plant. Most of the coffee growers have two-story square frame houses each with several additional small buildings for prepara-

FIGURE 31.—Large cattle ranch in the arid southwest near Faro Cabo Rojo. The cows are milked once a day and also suckle their calves. About 1 gallon of milk is obtained from each cow. The feed consists entirely of guinea grass and a few other grasses.

Rancho de ganado en el suroeste árido de la isla, cerca del Faro Cabo Rojo. Las vacas se ordeñan una vez al día y también alimentan sus becerros. Solamente como 1 galón de leche se obtiene de cada vaca. La alimentación del ganado consiste de yerba de guinea y otras yerbas.

FIGURE 32.—Small tobacco farm in a limestone valley south of Isabela, on Sabana Seca sandy clay loam. Note the thatch-roofed tobacco barn and the small house.

Pequeña finca de tabaco en un valle calizo al sur de Isabela en Sabana Seca areno-arcilloso lómico. Nótese el rancho para tabaco techado de yaguas y la casita.

tion of the coffee (fig. 29). Many of the dairy farmers have modern dairy barns (fig. 30). The cattle ranches have substantial corrals but very few buildings (fig. 31). The tobacco growers have large tobacco barns but small houses averaging two rooms and a lean-to for cooking (fig. 32).

Charcoal is universally used for cooking and ironing. One seldom sees any outbuildings around the small farm dwellings. At night chickens and pigs stay under the houses which are elevated off the ground (fig. 33). Very few of the jibaros have storage sheds, and the crops grown are either consumed or sold immediately to the small rural stores nearby, which frequently sell some of these products back to the original seller at a later date. This does not apply to the more enterprising farmers, such as owners of sugarcane, citrus, coffee, or tobacco farms. Most of the commercial crops are sold a few months

FIGURE 33.—Well-built farm dwelling elevated 1 or 2 feet from the ground for better ventilation. At night the doors and windows are closed. Poultry and small livestock stay under the house during rains and at night. Storage sheds are rarely seen. The 5-gallon cans are used as water containers. The water supply may be a mile or more away.

Casa de campo bien construída, elevada como dos pies de la tierra para mejor ventilación. De noche se cierra las puertas y ventanas. En tiempo lluvioso y de noche las aves de corral y otros animales pequeños duermen debajo de la casa. Rara vez se vé un almacén. Las latas de 5 galones se usan como recipientes de agua y la fuente de abastecimiento puede estar a una milla o más de distancia.

after they are harvested. Some of the centrals may store a part of their sugar in the hope of obtaining higher prices.

Most of the fences around grapefruit orchards, pineapple fields, and pastures are good; those around sugar central holdings range from fair to good; and those of most of the other farms are poor or lacking. The type of fence in most common use among the small landowners is formed by the maya, a thorny spreading plant from 3 to 4 feet tall. Many of these plants have a spread ranging from 6 to 9 feet. They make a very effective fence; but if allowed to grow unpruned, they cover too much of otherwise valuable land. Boundaries between the farms in the sugarcane, grapefruit, tobacco, and pasture lands generally are definite and distinct, but in the coffee and forest lands they are indefinite and hard to determine.

CLIMATE

Puerto Rico is less than 20° north of the Equator, rather small in area, and far from any large land masses. It has, as may be expected, a tropical, uniform, oceanic climate, and nearly ideal conditions exist for a heavy precipitation over most of its area. The moisture-laden northeast trade winds, over the warm waters of the ocean, blow almost continuously during the day and strike Sierra de Luquillo at right angles. The air is diverted upward where it expands because of less pressure at the higher elevations and is cooled below the dew point. Condensation then takes place, and generally it is followed by rain. As a general rule, the higher the elevation, the less the pressure, the cooler the atmosphere, and, therefore, the greater the precipitation, to a maximum at elevations ranging from 4,500 to 6,000 feet, but these high elevations do not occur in Puerto Rico. As the rain clouds move southwest across the island they gradually give up their moisture.

The highest peaks and the northern and eastern sides of the mountain ranges receive the greatest rainfall; the small islands, the southern side of the main island, the northwestern corner, the eastern shore line, and the interior valleys receive the least. The reason for the low rainfall on the small islands and the low eastern coast line is because such obstacles as mountain ranges are not present to lower the temperature of the wind as it passes. Often the weather will be clear on the eastern coast, yet clouds will form at about 9 a. m. on Sierra de Luquillo, from 3 to 5 miles away, and rain will fall throughout most of the day.

The southern coast is dry for two reasons: (1) The wind usually has given up much of its moisture before it passes the high mountain crest and there is none to fall on the low southern side; (2)—which is also the reason the mountain valleys near Caguas, Cayey, Adjuntas, Rincón, Jayuya, and Utuado are drier than the nearby hills after the wind passes the high northern mountain ridges it blows down the steep southern slopes and becomes compressed and denser at the lower levels and so is warmed. It then can hold not only all the moisture it has, but can take up some through evaporation. The greater the evaporation, the drier the soil and the more sparse the vegetation. The northwestern corner of the island is drier than the interior because this area is to the north of the winds that have been cooled by any of the mountain ranges or peaks and the wind is warm and holds most of its moisture. Inland, for a mile or more, the entire north coast is dry for the same reason.

The average annual precipitation ranges from less than 30 inches in the southwestern part of the island to nearly 200 inches on the highest peaks in Sierra de Luquillo. Table 3 gives the rainfall, by months, at most of the United States Weather Bureau stations on the island. Table 4 gives the normal monthly, seasonal, and annual temperature and precipitation, as recorded by the Weather Bureau stations, at Fajardo, Río Piedras, and Isabela along the north coast; San Lorenzo, Aibonito, and Maricao, in the interior; and Maunabo, Ponce, and Ensenada along the south coast. These tables show that there are no definite seasons, but rather a rainy period from May 1 to November 1, inclusive, and a dry period the other 6 months. Throughout the winter, however, many showers occur, but the heavy torrential rains take place in the summer.

TABLE 3.—*Mean monthly and annual rainfall at a number of places in Puerto Rico based on all available records (1899–1928)*

Station	Length of record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
SOUTH COAST AND ISLANDS														
	Yrs.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
Ensenada	27	0.72	1.17	1.22	1.98	2.78	2.17	1.75	2.70	3.75	4.02	3.34	1.11	26.71
Potala	21	.86	1.27	1.04	2.21	2.65	2.10	2.42	3.79	4.61	4.88	3.42	.99	30.24
Santa Isabel	28	1.04	1.01	1.11	1.62	3.45	2.62	2.85	3.52	4.46	5.93	4.10	1.97	33.68
Isla de Mona	11	1.05	2.32	2.44	2.09	3.15	2.75	3.36	2.97	4.38	4.22	4.06	2.14	34.93
Ponce	28	1.01	.99	1.44	2.08	3.06	3.46	2.97	4.16	4.97	6.45	4.05	1.22	35.86
Isla de Culebra	7	2.88	2.15	2.10	1.77	4.54	2.72	2.73	4.70	5.15	4.28	5.53	2.62	41.17
Aguirre	30	1.38	1.57	1.52	1.88	3.76	4.74	4.48	4.65	6.22	6.46	4.13	1.86	42.65
Isla de Vieques	30	2.95	2.53	2.21	2.68	3.53	3.96	4.24	4.55	6.12	6.26	5.77	3.35	48.15
Josefa	28	1.74	1.95	1.86	2.04	4.16	5.18	5.13	4.52	6.95	7.62	5.36	2.12	48.63
Guayama	18	2.11	2.37	2.04	2.17	4.34	5.11	5.19	4.52	6.91	7.23	5.52	2.46	49.97
Juana Díaz	30	1.07	1.71	2.10	3.50	4.63	4.51	3.87	6.08	7.24	8.65	5.08	1.80	50.24
Coamo	8	3.43	1.48	1.77	3.80	4.26	5.60	3.60	5.97	5.26	6.81	6.43	4.04	52.45
Peñuelas	21	1.58	2.69	2.04	4.19	4.90	4.15	4.82	6.10	6.99	8.56	5.85	2.07	53.94
NORTH COAST														
Camuy	16	4.03	2.92	3.25	3.32	3.74	2.49	3.53	3.78	4.56	4.67	6.85	4.36	47.50
Isabela	30	3.43	2.69	2.58	3.53	5.27	3.89	3.49	4.82	5.05	4.94	7.41	4.62	51.72
Arecibo	26	5.44	4.07	4.05	4.50	5.50	3.32	5.01	4.52	4.83	4.73	8.52	6.07	60.56
Barceloneta	14	5.77	4.64	3.52	3.75	5.50	3.17	5.88	4.31	5.47	5.03	8.40	5.36	60.80
San Juan	30	4.14	2.76	3.10	4.24	5.37	5.21	6.02	6.12	6.17	5.74	6.99	5.47	61.33
Cangrejo	8	4.67	3.78	2.39	3.98	5.83	5.59	6.47	4.54	6.34	7.28	7.86	4.99	63.72
Fajardo	30	3.50	3.01	3.11	3.71	5.40	4.96	5.88	5.54	7.30	8.34	8.64	4.86	64.25
Manatí	30	5.14	4.22	4.66	5.26	5.89	4.16	6.03	5.00	6.45	5.68	8.27	6.75	67.51
Dorado	21	5.45	4.19	3.94	4.67	5.69	4.65	6.68	5.95	6.15	5.38	8.92	6.21	67.88
Río Piedras	28	4.69	3.47	3.78	4.96	6.65	6.16	7.85	7.54	8.05	6.54	7.30	6.47	73.46
Bayamón	30	4.89	3.21	3.82	5.00	7.33	7.44	8.38	8.40	7.76	6.57	7.54	6.24	76.58
PROTECTED VALLEYS OF THE INTERIOR														
Cayey	30	3.21	2.83	2.90	3.47	4.44	5.64	6.22	6.58	6.60	6.37	6.26	4.13	58.65
Caguas	30	3.86	2.44	2.97	3.84	5.03	5.92	7.10	6.43	6.90	7.32	6.37	4.79	62.97
San Germán	30	1.96	2.65	3.52	6.49	5.59	4.31	5.79	7.45	7.39	9.05	6.86	3.19	64.25
Juncos	19	3.24	2.78	2.88	3.61	5.59	5.70	7.55	7.49	8.02	8.20	7.35	3.02	65.43
Cabo Rojo	22	2.15	2.98	3.84	5.36	5.55	4.57	7.64	7.94	9.04	8.75	5.73	2.80	66.35
Jayuya	20	2.25	2.20	5.53	7.26	6.38	3.95	6.02	5.89	10.37	8.10	7.02	2.45	67.42
Maunabo	30	3.70	3.27	3.45	3.24	5.86	8.22	7.15	7.10	9.50	9.81	8.55	5.00	74.85
Comerío Falls	22	6.63	4.53	4.85	5.78	5.70	4.52	7.91	8.29	7.69	6.70	8.57	7.11	78.28
Orocovis	11	5.63	3.15	5.89	4.93	9.37	4.13	7.35	4.58	8.34	8.93	8.98	7.68	78.96
Yabucoa	24	3.98	4.04	3.04	3.73	7.10	7.08	7.75	7.55	10.24	9.82	9.20	4.92	78.45
Utuado	15	3.72	1.85	3.64	6.94	8.19	7.86	6.47	7.68	12.75	10.24	7.66	3.89	80.89
INTERIOR														
Cidra	23	6.67	4.14	4.32	5.14	7.49	7.20	8.33	10.16	7.35	5.90	6.86	6.89	80.45
Coloso	30	2.13	2.09	2.97	4.90	9.92	12.20	9.37	9.99	10.30	8.32	6.79	2.60	81.58
Mayagüez	30	1.89	2.20	3.31	5.52	7.94	9.00	11.23	11.26	10.78	9.99	6.42	2.62	82.16
Carite Camp	18	4.79	4.94	4.73	4.70	6.57	7.55	9.63	7.61	9.12	10.38	8.17	4.71	82.90
Humacao	30	4.08	3.48	3.56	4.54	8.54	8.62	8.36	8.54	9.92	9.90	9.03	4.92	83.49
Guajataca	8	4.00	4.47	4.32	7.86	7.97	8.58	6.80	8.07	11.42	8.87	6.59	5.17	84.12
Añasco	21	1.52	2.90	2.82	5.63	8.71	10.15	11.63	12.21	11.05	10.47	6.26	2.84	86.19
Morovis	9	5.25	3.38	6.38	5.74	8.35	5.63	6.46	11.06	8.61	10.01	8.62	7.70	87.19
Toro Negro	18	3.88	4.39	4.57	8.43	9.02	6.64	7.48	7.54	13.01	14.50	10.90	4.64	95.00
Lares	24	3.26	3.60	4.39	9.16	11.74	9.99	8.46	9.26	12.23	12.32	8.79	5.03	98.23
Las Marías	17	2.75	2.61	4.72	6.49	12.37	10.66	9.34	12.14	13.24	12.37	8.97	3.72	99.38
San Sebastián	17	3.64	2.45	4.94	8.24	13.29	12.47	9.58	11.01	12.59	11.91	9.01	3.96	103.09
Maricao	18	1.92	3.14	4.65	8.36	10.77	9.18	12.75	13.40	13.26	15.80	9.37	3.68	106.28
Luquillo (La Perla)	9	8.21	3.37	6.54	11.27	14.94	13.75	14.56	11.14	12.24	13.94	16.23	9.36	135.55

TABLE 4.—*Normal monthly, seasonal, and annual temperature and precipitation at 9 Weather Bureau stations*

FAJARDO, P. R. ELEVATION 30 FEET

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
	° F.	*° F.*	*° F.*	*Inches*	*Inches*	*Inches*
December	77.5	90	60	4.88	2.67	3.06
January	76.4	89	57	3.55	3.93	1.75
February	76.2	92	59	2.97	2.25	6.63
Winter	76.7	92	57	11.40	8.85	11.44
March	76.8	92	60	2.94	2.97	2.70
April	78.3	93	61	3.80	1.23	6.52
May	80.3	93	60	6.32	2.99	9.14
Spring	78 5	93	60	13.06	7.19	18.36
June	81.3	93	68	5.28	1.58	11.92
July	81.8	93	69	5.87	6.14	5.62
August	82.2	95	64	6.05	5.40	8.81
Summer	81.8	95	64	17.20	13.12	26.35
September	81.6	96	68	7.79	3.20	14.28
October	80.8	98	65	8.30	10.95	12.20
November	79.3	93	63	8.25	3.31	15.34
Fall	80.6	98	63	24.34	17.46	41.82
Year	79.4	98	57	66.00	[1] 46.62	[2] 97.97

RIO PIEDRAS, P. R. ELEVATION 75 FEET

Month	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
December	73.9	90	54	5.03	4.67	5.16
January	73 1	89	54	4.73	10.51	7.45
February	73.3	91	55	3.59	5.08	1.54
Winter	73.4	91	54	13.35	20.26	14.15
March	73.8	91	57	2.85	2.29	8.32
April	75.5	92	58	6.38	.69	4.82
May	77.7	93	62	8.87	3.96	12.20
Spring	75.7	93	57	18.10	6.94	25.34
June	78.8	93	63	5.76	3.17	9.86
July	78.8	94	63	7.08	4.04	17.38
August	79.1	95	58	6.13	6.33	6.56
Summer	78.9	95	58	18.97	13.54	33.80
September	79.6	95	57	7.59	4.46	8.82
October	78.9	95	64	6.91	4.10	11.82
November	77.0	94	62	7.89	4.84	12.89
Fall	78.5	95	57	22.39	13.40	33.53
Year	76.6	95	54	72.81	[3] 54.14	[4] 106.82

ISABELA, P. R. ELEVATION 275 FEET

Month	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
December	76.2	94	57	4.61	5.10	6.41
January	75.1	92	58	3.34	4.30	6.70
February	74.8	94	59	2.81	1.10	.29
Winter	75.3	94	57	10.76	10.50	13.40
March	75.7	94	59	2.87	1.50	2.64
April	77.0	96	60	3.36	3.00	4.70
May	78 5	97	62	6.40	1.95	15.89
Spring	77.1	97	59	12.63	6.45	23.23

See footnotes at end of table.

TABLE 4.—*Normal monthly, seasonal, and annual temperature and precipitation at 9 Weather Bureau stations*—Continued

ISABELA, P. R. ELEVATION 275 FEET—Continued

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
	° *F.*	° *F.*	° *F.*	*Inches*	*Inches*	*Inche*
June	79.6	98	63	4.78	.85	5.67
July	80.4	96	65	3.97	3.30	11.87
August	80.5	99	65	5.15	1.90	9.17
Summer	80.2	99	63	13.90	6.05	26.71
September	80.3	99	63	5.60	3.00	16.80
October	79.7	97	60	5.42	6.80	7.14
November	78.4	96	60	7.02	3.10	6.22
Fall	79.5	99	60	18.04	12.90	30.16
Year	78.0	99	57	55.33	[5] 35.90	[6] 93.50

SAN LORENZO (VALDES FARM), P. R. ELEVATION 203 FEET

Month	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
December	74.6	92	53	4.95	0.95	3.29
January	72.9	90	54	3.51	2.70	2.45
February	72.9	92	53	2.39	2.75	4.88
Winter	73.5	92	53	10.85	6.40	10.62
March	73.6	93	53	3.14	2.48	2.74
April	76.2	93	57	3.43	2.06	11.25
May	78.0	95	53	9.23	3.89	17.77
Spring	75.9	95	53	15.80	8.43	31.76
June	78.8	94	60	6.55	2.66	10.23
July	78.8	94	64	6.76	9.78	9.10
August	79.4	103	63	7.56	6.00	4.81
Summer	79.0	103	60	20.87	18.44	24.14
September	79.0	101	60	10.00	6.47	20.97
October	78.1	96	60	8.06	5.28	15.27
November	76.3	97	58	7.93	3.08	18.97
Fall	77.8	101	58	25.99	14.83	55.21
Year	76.6	103	53	73.51	[1] 48.10	[2] 121.73

AIBONITO, P. R. ELEVATION 2,000 FEET

Month	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
December	69.4	85	49	4.44	2.40	2.64
January	67.9	89	43	3.74	3.65	5.51
February	67.8	88	43	3.13	1.05	2.21
Winter	68.4	89	43	11.31	7.10	10.36
March	68.6	89	40	3.45	2.95	1.95
April	69.9	88	45	3.82	2.95	3.45
May	71.9	92	48	6.00	5.15	6.10
Spring	70.1	92	40	13.27	11.05	11.50
June	73.4	90	49	4.16	1.05	3.72
July	74.4	90	52	5.21	2.40	16.62
August	74.8	90	52	6.10	2.47	15.47
Summer	74.2	90	49	15.47	5.92	35.81
September	74.1	90	51	6.54	5.20	8.34
October	73.2	92	50	7.53	3.09	19.43
November	71.6	91	50	6.43	4.05	8.18
Fall	73.0	92	50	20.50	12.34	35.95
Year	71.4	92	40	60.55	[7] 36.41	[8] 93.62

See footnotes at end of table.

TABLE 4.—*Normal monthly, seasonal, and annual temperature and precipitation at 9 Weather Bureau stations*—Continued

MARICAO, ELEVATION 1,500 FEET

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
	° F.	*° F.*	*° F.*	*Inches*	*Inches*	*Inches*
December	70.9	89	50	3.72	3.05	1.60
January	70.1	88	50	2.20	2.30	2.80
February	69.7	90	48	3.02	.40	1.75
Winter	70.2	90	48	8.94	5.75	6.15
March	69.9	92	48	5.05	1.78	15.65
April	71.1	90	50	8.10	5.40	10.65
May	72.1	93	50	12.18	9.50	13.80
Spring	71.0	93	48	25.33	16.68	40.10
June	73.3	95	54	8.11	12.40	9.50
July	74.0	92	55	11.70	8.52	19.95
August	74.7	92	55	14.62	8.38	16.45
Summer	74.0	95	54	34.43	29.30	45.90
September	73.4	90	55	15.93	10.28	8.45
October	72.7	90	50	15.32	13.74	28.85
November	72.1	90	50	8.77	5.27	11.15
Fall	72.7	90	50	40.02	29.29	48.45
Year	72.0	95	48	108.72	[7] 81.02	[4] 140.60

MAUNABO, ELEVATION 50 FEET

Month	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
December	78.0	93	61	5.48	2.30	8.47
January	76.3	90	59	4.53	8.14	1.60
February	76.7	93	58	3.33	3.89	2.62
Winter	77.0	93	58	13.34	14.33	12.69
March	77.0	93	57	3.26	1.10	.70
April	78.8	94	61	3.29	.60	5.50
May	79.8	95	62	7.27	3.39	13.93
Spring	78.5	95	57	13.82	5.09	20.13
June	81.1	96	62	8.31	4.68	17.70
July	82.2	95	68	7.35	4.15	9.55
August	82.7	96	62	7.56	4.60	14.90
Summer	82.0	96	62	23.22	13.43	42.15
September	81.8	95	66	9.58	3.82	13.95
October	81.1	96	65	9.86	10.75	15.15
November	79.6	94	61	8.31	5.20	9.55
Fall	80.8	96	61	27.75	19.77	38.65
Year	79.6	96	57	78.13	[9] 52.62	[2] 113.62

See footnotes at end of table.

TABLE 4.—*Normal monthly, seasonal, and annual temperature and precipitation at 9 Weather Bureau stations—Continued*

PONCE, ELEVATION 80 FEET

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
	° *F.*	° *F.*	° *F.*	*Inches*	*Inches*	*Inches*
December	77.0	91	57	1.17	0.97	0.10
January	75.4	90	57	1.05	.05	1.34
February	75.4	90	55	1.23	.56	.86
Winter	75.9	91	55	3.45	1.58	2.30
March	76.0	91	58	1.29	.54	.45
April	77.4	93	59	1.87	1.67	2.62
May	79.5	95	61	3.62	2.03	3.69
Spring	77.6	95	58	6.78	4.24	6.76
June	80.7	96	58	3.60	.89	7.74
July	81.0	95	58	2.73	.20	3.14
August	81.6	96	64	4.20	2.52	17.20
Summer	81.1	96	58	10.53	3.61	28.08
September	81.3	98	68	5.14	7.75	3.19
October	80.5	95	61	5.70	1.74	8.20
November	79.0	94	60	3.84	.87	10.20
Fall	80.3	98	60	14.68	10.36	21.59
Year	78.7	98	55	35.44	[10] 19.79	[11] 58.73

ENSENADA, ELEVATION 50 FEET

Month	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
December	75.4	95	51	1.27	0.53	3.85
January	74.3	95	53	.84	.10	2.10
February	74.3	92	51	1.49	.18	.80
Winter	74.7	95	51	3.60	.81	6.75
March	75.1	100	52	1.43	.54	2.25
April	76.2	100	56	1.82	.93	.00
May	77.5	94	58	3.41	.32	7.70
Spring	76.3	100	52	6.66	1.79	9.95
June	79.0	99	58	2.40	2.00	3.90
July	79.3	95	60	1.71	.06	.70
August	79.6	98	60	3.01	.82	3.30
Summer	79.3	99	58	7.12	2.88	7.90
September	79.7	98	56	4.37	1.29	10.80
October	78.6	97	59	3.94	3.27	9.72
November	77.1	96	58	3.66	1.30	7.95
Fall	78.5	98	56	11.97	5.86	28.47
Year	77.2	100	51	29.35	[12] 11.34	[13] 53.07

[1] For 1926.
[2] For 1931.
[3] For 1920.
[4] For 1927
[5] For 1923.
[6] For 1932.
[7] For 1913.
[8] For 1916.
[9] For 1930.
[10] For 1929.
[11] For 1909.
[12] For 1922.
[13] For 1933.

A rainfall of 30 inches in Puerto Rico is equivalent in effectiveness to about 15 inches in the United States. The high evaporation combined with high temperatures, low relative humidity, and constant winds tends to cause semiarid conditions even where the average annual rainfall is 45 inches. In San Juan the evaporation from a free water surface exceeds the precipitation, but in the moist mountain districts the precipitation probably far exceeds the evaporation. The evaporation is much higher in comparison to the rainfall during the dry winter than at other seasons, and, as crops grow throughout the year, irrigation is sometimes necessary even in areas having an average annual rainfall of 65 inches. Some of the soils, because of their permeable physical characteristics, require water at frequent intervals in order to insure maximum crop production. This is especially true with the red soils derived from limestone, which occur from Bayamón to Aguadilla. Extensive irrigation systems are in operation in most cultivated areas having less than 50 inches of rainfall, and some pumping plants have been installed for the irrigation of sugarcane and grapefruit in areas receiving an average annual rainfall of 68 inches.

The temperature, although tropical, is cooled during the day by the moisture-laden trade winds and at night by the land breezes that blow from the cool mountains to the coast. Mean monthly temperatures along the warmer dry coast towns range from about 75° F. in the winter to about 80° during the summer. Throughout the year the moist mountain areas are about 5° cooler than those along the coast. Extremes of temperature within 24 hours are very rare, except during hurricanes. The temperature seldom rises higher than 90°, and even in the highest, coolest parts of the island it seldom falls below 50°; at least there are no records of very low temperature. Fire is not needed in any of the homes, except for cooking and ironing. Frost is unknown, and rarely does one hear of sunstroke. Dense fogs occur only in the mountain valleys and on peaks.

The mild uniform temperature, low relative humidity combined with invigorating breezes, and the mountainous character of most of the island make it a very agreeable place in which to live. Sunshine occurs daily over most of the island, with the exception of a few days each year, and the ultraviolet rays of the Tropics are beneficial to plants, animals, and mankind. The high precipitation, however, has caused destructive leaching in many soils, and they are acid, low in bases, and lacking in plant nutrients. The plants produced from the leached soils do not seem to be so nutritious as those grown on neutral or alkaline soils high in bases.

The climate (*45, pp. 4–12*) is nearly ideal for a 12-month growing period for such tropical crops as coffee, sugarcane, pineapples, bananas, mangoes, coconuts, yautia, and yuca, but it is not so good for alfalfa and berries. Such crops as wheat, oats, barley, apples, and peaches are not grown. The imported dairy cattle, hogs, goats, and chickens suffer somewhat because of the climate, but oxen, horses, and mules seem to thrive. Sheep and beef cattle do much better in cooler climates. The climate has had very little direct effect on the distribution of most of the livestock and poultry, except turkeys which are much more prevalent in the dry hot areas than in the moist districts, because the drier areas are less favorable for the many harmful diseases that beset turkeys.

During the progress of the soil survey a rainfall map (fig. 34) of the island was compiled from rainfall data furnished by the United States Weather Bureau, owners of sugar centrals, and other landowners, as well as from information obtained from the correlation that exists between soil climate and the following: Plant species, growth of vegetation, soil erosion, soil color, soil development, elevation, and, to some extent, rural population.

There is very little noticeable correlation between the temperature and plant species, because there is only about 10° or 15° F. difference, for any length of time, between the coolest and warmest parts of the island. Such plants as wild raspberries, many kinds of flowers, and coffee grow better and produce higher yields in the cool mountains than on the warm coastal plain, but they are not limited to the cool mountains. Some of the mosses and vegetation on the highest peaks probably are restricted to the cool districts, but they are of minor importance. The quantity of rainfall, however, is the limiting factor for the distribution of many plant species. The sudden change in amount of precipitation is reflected so much in the native vegetation, that within a distance of a very few miles and a descent of a few hundred feet, one may pass from a luxuriant tropical rain forest to a shrub-covered desert.

The correlation that exists between plants and rainfall is in reality the relationship between plants and soil moisture, as is shown by the royal palms, which seldom grow on steep hillsides if the annual rainfall is less than 60 inches; but they will grow on level land if the annual rainfall is 50 or more inches; and they grow along drainageways if the annual rainfall is greater than 35 inches. Cacti and many of the thorny plants are confined mostly to sections having less than 40 inches of annual rainfall, but they grow abundantly in areas of higher rainfall if the soil is very permeable, droughty, and the relief steep, for instance, on some of the Rosario soils which are derived from serpentine and occur northwest of Yauco in a belt where the annual rainfall is more than 65 inches. The drought-resistant guinea grass grows abundantly in the valleys, but it ceases to grow on the adjacent hillsides having an annual rainfall of less than 30 inches, unless it has exceptionally good care. Coconuts will grow along the low coast regardless of the low rainfall, but they do not thrive on the hillsides unless the annual rainfall is greater than 40 inches. The húcar, or úcar, trees thrive either on hills or level land if the annual rainfall is 45 inches or less. The almácigo, tamarindo, algarrobo, and jagüey are conspicuous in almost all areas having an annual rainfall of 60 inches or less. This is also about the rainfall limit of barrilla and horquetilla grasses. The treeferns do not seem to grow in areas having less than 80 inches of annual rainfall, and generally with that rainfall they grow in the concave drainageways. The sierra palms are seldom conspicuous unless the annual rainfall is 100 or more inches. The characteristic moss vegetation of high peaks of Sierra de Luquillo requires more than 150 inches of rainfall annually.

Plant growth also is correlated with soil moisture. Sugarcane generally will be a failure when planted on steep hillsides, level sandy soils, or very impervious soils, in areas having less than 60 inches of annual rainfall. Low yields of sugarcane may be expected on level alluvial land in areas having less than 40 inches of annual rainfall, unless the land is irrigated. The valley south of Lajas, which has

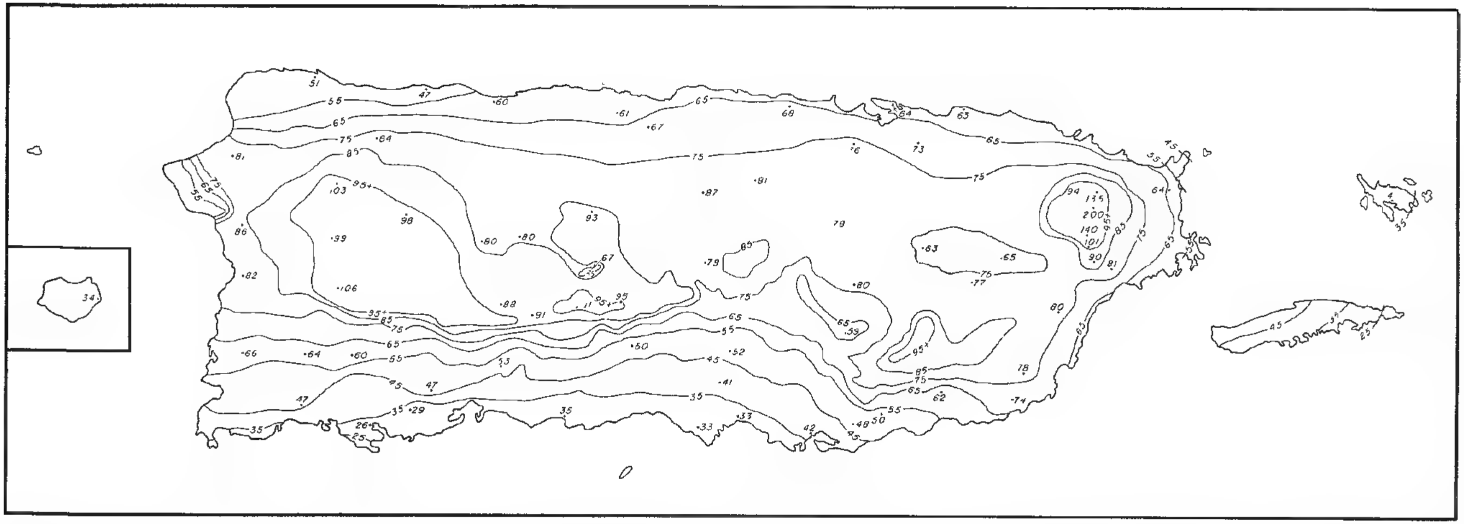

FIGURE 34. Rainfall map of Puerto Rico, compiled from data furnished by the United States Weather Bureau, owners of sugar centrals, and other landowners, and from information obtained from the correlation that exists between soil climate and the following: Plant species, growth of vegetation, soil erosion, soil color, soil development, elevation, and, to some extent, rural population.

Mapa de precipitación pluvial de P. R. compilado de los datos suplidos por el Negociado del Tiempo de los EE. UU., las centrales y otros agricultores, también de información obtenida de la correlación que existe entre el clima del suelo y lo siguiente: especies de plantas, vegetación, erosión, color del suelo, desarrollo del mismo, elevación, y hasta cierto punto, población rural.

an average annual rainfall of 45 inches, produces fair yields of sugarcane on the low level lands, but the adjacent hills to the south will produce only such crops as corn, beans, grass, and pasture, which require less water. In the eastern part of the island, near Ensenada Honda de Fajardo, where the annual rainfall is about 60 inches, much of the sugarcane planted on the hillside will be a failure, unless the rainfall is above the average; but sugarcane generally will range from fair to good on the adjacent level alluvial lands, where the sugarcane roots can penetrate deeply and obtain a much greater supply of moisture than on hillsides.

The amount of rainfall varies greatly within short distances, especially in sections having mountain barriers and where the mean annual precipitation is less than 70 inches. The north side of a high or medium-high east-west ridge may receive 10 inches more rainfall annually than the south side. In many areas receiving annually from 50 to 60 inches of rainfall, the north side of a hill will be cultivated to corn, beans, tobacco, and gandules, or pigeonpeas, and the south side will be in pasture. It is of the utmost importance for the agriculturist as well as for money-lending agencies to know as nearly as possible the boundaries of the areas receiving less than 60 inches of rain annually, as this is more or less the critical moisture zone. The success or failure of many hundreds of people depends on whether or not they attempt hillside farming in areas having less or more than 60 inches of annual precipitation. A person may be deceived greatly by the general appearance of the drier country, if he visits it during the rainy season.

It is noticed that in sections having from 50 to 60 inches of annual rainfall, there is more serious soil erosion than in any other part of Puerto Rico. (See fig. 23, p. 36.) There may not be so much erosion within this area as in more mountainous areas, but the harm resulting from erosion is more lasting. Erosion is more serious within this belt than elsewhere mainly because the rainfall is sufficient to encourage hillside farming by small farm owners who plant clean-cultivated crops, such as beans, corn, tobacco, and pigeonpeas, yet not sufficient for plants to make a quick dense growth as in more moist areas. One of the main reasons that soil erosion is not more destructive on the steep hillside farms in the areas of high rainfall is because vegetation grows so quickly and densely that the force of the water is checked and the soil granules are bound together by the plant roots. The areas receiving less than 50 inches of rainfall annually support a sparse growth of vegetation, but the farmers do not attempt to cultivate the steeper slopes nor do they overgraze their pastures to such an extent as do farmers in the areas of slightly more rainfall. Erosion in the dry areas is due mostly to sudden, intense showers that fall at the termination of long dry periods, when the grass is short, or sparse, and much of the ground is exposed. Within a week's time after the spring rains start, however, the grass reestablishes itself so that destruction from rains during the rest of the rainy season is greatly reduced.

Very few data are obtainable on the intensity of the rains in different parts of Puerto Rico. The intensity of rainfall and wind as recorded by the Weather Bureau station at San Juan is presented in tables 5 and 6. These tables show that the greatest amount of rain falling in 24 hours was 10.55 inches and the heaviest downpour in 2 hours was 4.67 inches. This high intensity of rainfall is one of the serious

factors in causing soil erosion on the sloping lands. The intensity of rainfall is greater in some other cities than at San Juan.

TABLE 5.—*Extremes of precipitation and wind at San Juan (1899–1935)*

Month	Precipitation			Wind			
	Date	Year	Greatest in 24 hours	Date	Year	Direction	Highest velocity [1]
			Inches				*Miles per hour*
January	3	1934	4.52	21	1921	Northeast	[2] 43
February	23–24	1918	4.84	6	1931	North	40
March	4–5	1927	3.64	12	[3] 1921	East	38
April	7–8	1915	6.72	10	1915	do	35
May	1–2	1902	4.81	6	1928	Northeast	34
June	11–12	1919	5.26	16	1908	Southeast	40
July	6–7	1901	4.05	23	1926	East	51
August	8–9	1899	6.26	22	1916	Northeast	70
September	13–14	1928	8.50	13	1928	do	[2] 149
October	30–31	1927	3.87	9	1916	North	41
November	11–12	1931	8.06	28	1917	Northeast	40
December	13–14	1910	10.55	3	[4] 1934	do	40

[1] Corrected to true velocitiy.
[2] Estimated.
[3] Also in 1935, March 10, from the northeast.
[4] Also in 1935, December 7, from the northeast.

TABLE 6.—*Excessive precipitation at San Juan, 1899–1935*

[Maximum amounts for short periods]

Duration of downpour (minutes)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Maximum
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
5	0.48	0.45	0.56	0.58	0.79	0.50	0.44	0.57	0.56	0.48	0.44	0.50	0.79
10	.88	.83	.98	1.01	1.02	.76	.72	.89	.91	.80	.82	.89	1.02
15	1.17	1.10	1.20	1.32	1.08	1.05	.96	1.28	1.31	1.05	1.19	1.19	1.32
30	1.77	1.26	1.50	2.06	1.80	1.62	1.60	2.16	2.09	2.00	2.23	1.47	2.23
60	3.19	2.00	1.55	2.46	3.03	2.13	2.10	3.18	3.43	3.01	3.48	2.67	3.48
120	4.26	2.35	1.79	3.57	3.46	2.98	2.60	3.58	4.21	3.30	4.67	3.55	4.67

The correlation between soil climate and soil color and development is very obvious. In the driest part of the island, or the part receiving less than 25 inches of annual rainfall, the mature soils are brown, and they would be classified with the Brown soil group in the United States. The areas receiving from 25 to 35 inches of annual rainfall have chestnut-colored soils and are classified as Chestnut or Reddish Chestnut soils. The soils in a moister belt are very dark grayish brown and are classified with the Chernozem. This area has an annual rainfall ranging from 35 to 45 inches. Within the areas having an annual rainfall ranging from 45 to 60 inches, the soils having nearly black surface soils are classified as Prairie or Reddish Prairie soils. Most of the nearly level soils occurring within the area having an annual rainfall ranging from 60 to 75 inches have grayish-brown surface soils and leached layers above the subsoil. These soils are classified as podzolic soils. Most of the soils occurring on the level or undulating areas having an annual rainfall ranging from 75 to 90 inches are red and deep, and are classified as lateritic, but the soils on the slopes are shallow and brown. The soils in belts where the annual rainfall ranges from 90 to 110 inches are deep and red, even on 80-percent slopes, and are considered lateritic. In areas where the annual rainfall exceeds 110 inches, the surface soil has a gray cast, and the color

is similar to that of Podzol soils. Soils produced from limestone or rocks high in bases may be exceptions to the above; for example, the soils north of San Sebastián and Lares are nearly black, although the annual rainfall is nearly 100 inches. These soils are derived from a medium soft limestone and are classified as Rendzina. In the extreme northwestern and the southwestern parts of the island, the average annual rainfall is 50 and 30 inches, respectively, but the soils are red because they are derived from rather hard limestone.

In most areas a correlation exists between the rainfall and the acidity of the soils. If the average annual rainfall is below 40 inches the soils are strongly alkaline, they generally effervesce at the surface when treated with dilute hydrochloric acid, and they have a pH value of 8 or more. Within this rainfall limitation are most of the "black alkali" areas. This rainfall belt, as shown on the map, includes only a small percentage of the island. Most of the soils receiving from 40 to 50 inches of rainfall annually range from neutral to alkaline in the surface soil and have free lime in the subsoil. Most soils having from 50 to 60 inches of annual rainfall are neutral or slightly acid in the surface soil and slightly alkaline in the subsoil. Most of the soils receiving from 60 to 70 inches of rainfall annually are acid in the surface soil and neutral in the subsoil. In most areas receiving more than 70 inches of annual rainfall the soils are acid in both the surface soil and subsoil. In most places the more poorly drained soils are the most alkaline, as the calcium carbonate does not leach readily under saturated soil conditions. Muck and peat soils are exceptions, as they are generally strongly acid. In some places in the arid districts, the soils are acid because they are derived from exceptionally acidic rocks and are low in soluble bases; for example, the soil mapped as Mariana clay loam near Lajas. Other soils are acid in dry areas because they are very old and probably were leached of their carbonate under a more moist climate than now exists. In general, soils derived from soft limestone will be alkaline even if the annual rainfall is more than 100 inches, but if the limestone is very hard and weathers slowly the soil might be acid if the annual rainfall ranges from 40 to 50 inches.

There is no uniform correlation between elevation and rainfall, but throughout the island the heaviest precipitation occurs on the high peaks. Southward from the east-west mountain ranges, the rainfall decreases with decreasing elevation, but on the north, east, and west sides the total amount of precipitation at the same elevation varies.

Climate, especially the two extremes of rainfall, seems to be a factor in the distribution of rural population. In the arid islands and along the southern coast of the mainland, few crops, except the drought-resistant grasses, can be grown without irrigation. Such areas that are not irrigated are sparsely populated, because only a few people to the square mile can obtain a living. Subsistence crops are not grown successfully in the areas of high rainfall, which occur in the rough, rugged, fog-swept mountains at an elevation above 2,000 feet. Therefore, such areas are sparsely populated. The rural population is most dense in those municipalities that have the average climate, combined with soils, such as those of the Múcara and Cataño series, that are better adapted to subsistence crops than to other crops.

Climate probably has had some effect on the distribution of the races. On the hot sandy coast the proportion of Negroes is much

higher than that of whites, but in the cool high mountains there are very few Negroes.

Puerto Rico is in the region of the eastern Caribbean Sea where tropical cyclones take place, and these storms are dreaded from one season to the next. Between 1825 and 1935, 22 hurricanes caused great destruction on the island. The hurricanes generally occur between August and October, and the more severe ones have caused nearly $50,000,000 worth of damage and the loss of nearly 3,000 lives. The wind velocity may be more than 120 miles an hour, and the rainfall may exceed 20 inches for a 24-hour period. Some of the most destructive storms were: San Narciso, in 1867; San Ciriaco, in August 1899; San Felipe, in September 1928; and San Ciprián, in 1932.[14]

The crops most affected by storms are coffee, grapefruit, and sugarcane. The coffee growers suffer the greatest loss, as it requires 6 or 7 years after the shade trees have been destroyed before the coffee trees become profitably productive again. The loss of several successive crops, as well as the expense of planting new shade and coffee trees, is extremely heavy on the one-crop coffee grower. The grapefruit growers may lose 80 percent or more of their year's crop and possibly from 10 to 20 percent of their trees, but the next year the crop may be as large as the average. The sugar centrals undergo heavy losses of buildings, machinery, and railroads, in addition to the loss in sugarcane yields and to the low sucrose content of the cane, caused by the rapid growth of suckers as soon as the cane is blown over by the wind. After a storm the sugarcane is much harder to cut, as it is usually in a tangled mass.

In addition to the damage to property, loss of life, and loss in crop yields, the torrential rains occurring during and following the hurricanes do unestimable damage in washing the soil from the hills and either depositing it on alluvial flats or carrying it far out into the sea. Floods cause considerable damage to property, crops, and human life. Occasionally parts of the islands are affected by earthquakes.

AGRICULTURE

Puerto Rico always has been and probably always will be an agricultural island. When Columbus landed there nearly 450 years ago, some of the native Indians were gardeners and produced root crops to be used for a part of their diet. Today more than 50 percent of the farms are less than 9 acres each in area and are made up of small garden patches. The majority of the people have been gardeners for a long time, and, doubtless, with the rapidly increasing population, a much larger proportion of them will obtain a part of their living in the future by growing subsistence crops. For several hundred years the principal crops grown by the jibaro farmers or gardeners have been bananas, corn, sweetpotatoes, beans, yautia, pigeonpeas, yuca, and ñames. These subsistence crops are relished by all the native people and, supplemented with rice, fish, and coffee, constitute the main diet of the masses.

Although these crops are of vital importance to many thousands of people, the commercial prosperity of the island depends on the production and selling price of three main cash crops—sugarcane, tobacco, and coffee. These crops have been grown for many years, mostly by

[14] It is customary to name the hurricanes after a saint whose birthday is nearest to the day of the storm.

farmers owning large tracts of land. Table 7 gives the acreage of the principal crops grown, and figure 35 shows the types of farming practiced throughout the island.

TABLE 7.—*Acreage of the principal crops grown in Puerto Rico, in stated years*

Crop	1899 [1]	1903 [1]	1909 [2]	1901 [2]	1929 [2]	1935 [3]
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Sugarcane	72,146	112,416	145,433	227,815	237,758	245,154
Coffee	197,031	177,754	186,875	193,561	191,712	182,316
Bananas	69,380	----	----	[4] 52,206	[4] 128,339	[4] 61,786
Corn	18,093	----	56,640	58,785	70,217	49,820
Tobacco	5,963	18,414	22,142	39,068	52,947	45,720
Sweetpotatoes	37,109	----	----	31,457	47,616	36,947
Beans	----	----	20,652	34,907	40,902	31,470
Yautia	12,256	----		----	16,683	17,596
Coconuts	5,447	2,931	[5] 17,555	[5] 26,307	[5] 30,357	[5] 23,227
Pigeonpeas	----	----	----	----	----	15,954
Grapefruit	----	----	[6] 3,379	[6] 4,763	[6] 9,485	[6] 11,429
Rice	8,667	----	16,138	11,749	5,244	9,386
Ñames	2,098	----	----	----	5,186	7,966
Plantains	----	----	----	[4] 6,449	[4] 7,729	[4] 7,436
Yuca	----	----	----	----	6,072	6,846
Cowpeas	----	----	----	----	----	3,379
Vegetables	----	----	----	----	11,962	3,616
Pineapples	----	----	[7] 2,530	[7] 946	[7] 1,827	[7] 1,487
Cotton	----	----	1,425	2,760	10,282	934
Minor crops	[8] 49,836	[8] 201,036	----	----	----	----

[1] See (*46, p. 17*).
[2] Federal census.
[3] From Puerto Rico Reconstruction Administration special census (*34*).
[4] Calculated on the basis of 625 plants to the acre. Many acres of these crops are interplanted with coffee. The same is true of oranges, which have not been included in this table.
[5] Calculated on the basis of 30 trees to the acre.
[6] Calculated on the basis of 70 trees to the acre.
[7] Calculated on the basis of 10,000 plants to the acre.
[8] The minor crops have not been separated.

Sugarcane was introduced 25 years after Columbus landed, and coffee plants were taken to the island about two centuries later. Tobacco has been grown for a long time but was not grown on a commercial scale until about 1880. The raising of cattle was an important enterprise during the early days. Pineapples and grapefruit were of little importance until occupation by the Americans. During the last 200 years there have been many fluctuations, both in the acreage and in the importance of the different crops, which will be fully discussed, crop by crop, in the latter part of this section.

The history of early land tenure in Puerto Rico, as in nearly all newly settled countries, is vague. Undoubtedly the island once was covered with dense forests which varied in density and in the size of trees from place to place according to the climate and soil. The clearing of the forests by Indians, in preparation of the land for their root crops, was confined mostly, but not entirely, to the land along the coast. The more peaceful Arawak Indians seldom dared cultivate land in full view from the sea, but confined their farming to concealed places along inland valleys and along the river flood plains a short distance from the coast. The early Spanish settlers practiced agriculture only on the coastal lowlands and river flood plains near the small settlements. Later, most of the land held by the Spaniards was in large grants, many of which included the good level alluvial lands that were soon planted to sugarcane. Now, with few exceptions, cane occupies all the best soils. Coffee and tobacco were planted on the steeper, more acid, and less fertile land.

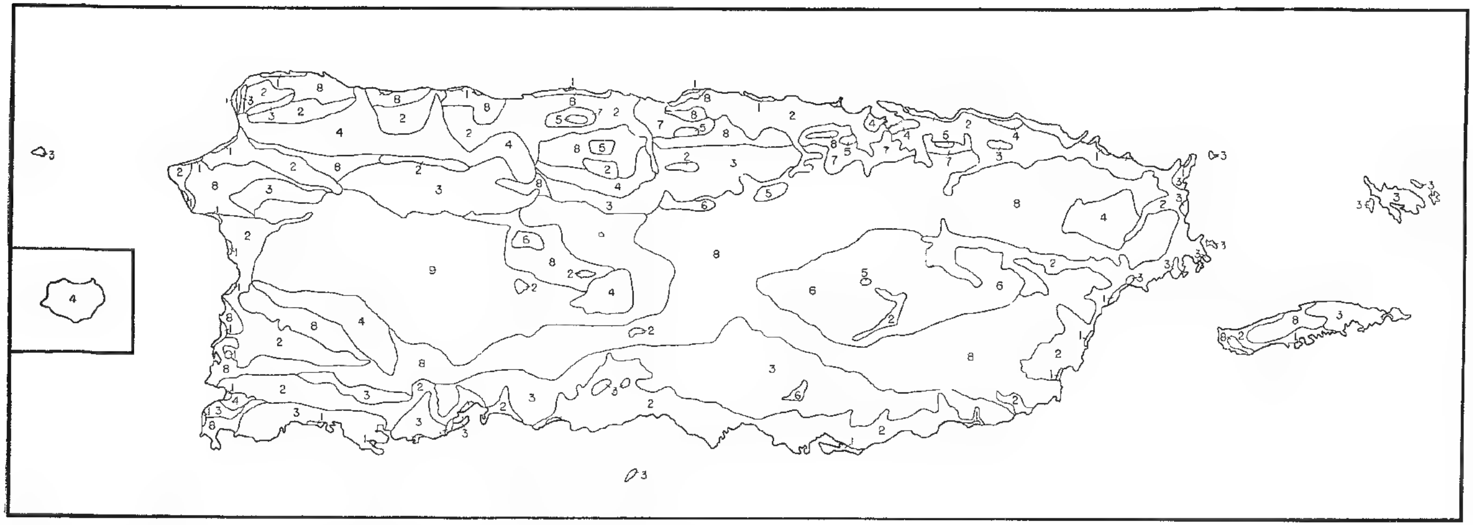

FIGURE 35.—Map of Puerto Rico, showing the different types of farming: 1, Coconuts; 2, sugarcane; 3, pasture and some subsistence crops; trees and some subsistence crops; 5, pineapples; 6, tobacco; 7, grapefruit; 8, subsistence crops; and 9, coffee.

Mapa de los siguientes cultivos en Puerto Rico: 1, Cocos; 2, caña de azúcar; 3 pastos y algunos cultivos de subsistencia; 4 árboles y algunos cultivos de subsistencia; 5, piñas; 6, tabaco; 7, toronjas; 8, cultivos de subsistencia; y 9, café.

FIGURE 36.—See legend on page 63.

Within the last 30 years most of the sugarcane estates and haciendas have been enlarged, and now many are owned by sugar centrals, many of which control from 1,000 to 10,000 acres. The best and most productive lands, therefore, are under the control of a comparatively few individuals or corporations. These lands, however, are efficiently and scientifically managed and now produce much higher yields than they did when they were held in small holdings and managed by the owners.

The coffee fincas always have been in large tracts, compared with the size of the minor truck farms. The tobacco farms range from very small to rather large. Tobacco is mostly grown by small farmers; 80 percent have less than 3 acres. From the beginning, the livestock ranches have included large tracts and probably will continue to do so. Owing to irrigation projects on the south coast, many large cattle ranches have been converted into checkerboard-patterned fields occupied exclusively by sugarcane (fig. 36). The average size of the commercial pineapple and grapefruit farms is about 200 and 100 acres, respectively, and their size has changed but little since they were started about 30 years ago. Many small farms have a few acres in pineapples or grapefruit.

The minor truck farms or gardens have changed considerably since the early days. At one time the most common practice of the jibaros was to cut the virgin trees, probably sell some timber but burn most of the limbs and branches on the land, then plant subsistence crops. This practice prevailed not only in the mountains but also on the better lands. In the olden times the jibaros had as large an acreage as they cared to cultivate even on the good alluvial lands. Later, when land became more valuable and sugarcane more important, the owners of the haciendas bought almost all of the level alluvial land, and the owners of the small tracts had to work for wages or buy other places on less desirable land. The owners of the haciendas, however, allowed the peon helper to have a small garden on the rich alluvial land. Gradually the alluvial land became too valuable for the production of subsistence crops, and the population increased so rapidly that the jibaros were crowded farther and farther into the steep mountainous country. As the jibaro family increased and married, the farm was divided and a part given to the sons or the farm products were shared with all members of the family.

At present these small gardeners live on steep hills where the soil is shallow or on very sandy level areas near the coast. In both situations the soils are poorly adapted for any of the main commercial crops, but, fortunately for the jibaro, they are fairly well adapted to subsistence crops. The hill land is steep, and, owing to much erosion, which is accelerated when clean-cultivated crops are planted, the surface soil becomes thin or is entirely washed away, but, as the subsoil and parent rock are soft and fairly rich in bases and plant nutrients,

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FIGURE 36.—Checkerboard-patterned irrigated sugarcane fields on Machete clay loam and Machete clay, which formerly were range land for livestock. Note the modern sugar central in the lower left-hand corner and the old hacienda in the upper right-hand corner. (Photograph taken by U. S. Navy.)

Campos de caña en forma de tablero de damas, bajo riego en Machete arcilloso lómico y Machete arcilloso, y que antiguamente eran pastos. Nótese la moderna central en la parte baja a la izquierda y la antigua hacienda en la parte de arriba a la derecha. (Fotografía tomada por la Marina de los EE. UU.)

the crops produced are of a better quality and more abundant than those grown on the deeper, less eroded, more leached acid soils such as occur in the coffee districts. The shallow young soils can maintain their productivity better under the jibaros' system of farming than can most of the older soils. The jibaros rarely use fertilizer, and they frequently plant three or four crops on the same land year after year. When viewed from the air, these small irregular-shaped garden patches give the landscape an appearance of an intricate mosaic pattern.

Nearly all of the sandy soils along the coast that are used extensively by the jibaros for gardens are fairly good for root crops and other subsistence crops. Yields are seldom high unless fertilizers are used, but fair crops are obtained and help in keeping the people from starvation.

According to the 1935 census of the Puerto Rico Reconstruction Administration (*34*), the average-sized farm is 36.2 cuerdas. The average farm for each municipality ranged from 15.6 cuerdas in Aguada, where most of the land is in subsistence crops, to 1,001.1 cuerdas in Santa Isabel where most of the cultivated land is in sugarcane and the uncultivated land in cattle ranches. There are 52,790 farms on the island, 25,326 of which are between 3 and 9 cuerdas in size and only 335 are 500 cuerdas or more.

The average value of land and buildings per cuerda was $81.69 in 1935 and in 1920 was $74.80. Land values range from nearly $1,000 a cuerda for the very best irrigated land on the south coast to less than $5 for that on rough limestone hills in either the dry district on the south coast or in the haystack hill area on the north coast.

According to the 1935 census, 18.7 percent of the farms are operated by tenants, 4.6 percent by managers, and 76.7 percent by owners or part owners. Most of the tenant farms are rented on a cash basis, and some of the good sugarcane land rents at prices ranging from $10 to $30 an acre. The planter usually pays the taxes, which may be more than $5 an acre. Many leases of the cane land are for a period ranging from 10 to 20 years.

Very often sugar centrals advance money to the nearby colonos, or small farmers, who send their cane to be ground at the central's factory. The transaction is in the form of a contract. The sugar central agrees to grind the colono's cane and may advance him $20 or more an acre for the first year's planted crop and less for the ratoon crops. The centrals charge interest and usually exercise some control over the cultivation and management of the crop. The price paid to the colono usually depends on the percentage of sucrose in the cane. Many contracts specify that the cane grown by the colono must have at least the minimum sucrose content and purity required. If the cane does not reach the minimum requirement, the grower is not remunerated, as the cost of grinding equals or is greater than the value of the cane.

Buyers of tobacco and cotton often advance money to the planters of these crops. The Federal Intermediate Credit Bank makes crop loans for the production of coffee, tobacco, and other crops.

According to the Federal census, the amount of money expended for fertilizer, including manure, was only $911,412 in 1909, but nearly six

times that amount, or $5,697,465, was spent in 1919. In 1929, $5,401,-187 was spent by the 18,540 farmers reporting. This was almost one-eighth of the total value of all vegetable, field, and orchard crops for 1929. The municipalities expending the largest amount for fertilizers in 1929, ranking in the order named, are: Salinas, Humacao, Guánica, Arecibo, Caguas, Fajardo, Bayamón, and Cayey. All these municipalities, except Cayey, have a very large acreage in sugarcane. Arecibo and Bayamón have considerable acreages in fruits, and Cayey has a large acreage in tobacco.

The use of commercial fertilizer is general for such crops as sugarcane, grapefruit, tobacco, pineapples, ñames, and some vegetables. Very little is used for coffee, coconuts, corn, minor crops, and pasture. The municipalities using the greatest amount of fertilizer are those that have the largest acreages of sugarcane. Most of the fertilizer is purchased ready mixed, and about 600 pounds to the acre are used for cane, from 800 to 1,000 pounds for grapefruit and tobacco, and about 1,200 pounds for pineapples. The grades used are discussed under the agriculture of each crop. The potash salts for the preparation of the mixed fertilizers are imported directly from Germany, the nitrate of soda from Chile, and the sulfate of ammonia, calcium cyanamide, and calcium superphosphate are brought from the United States.

According to the Annual Book on Statistics issued by the Department of Agriculture and Commerce of the insular government, Puerto Rico imported, during the fiscal year 1938-39, a total of $75,684,719 worth of merchandise from the United States and $7,039,563 worth from foreign countries. Of the amount from foreign countries, more than $1,000,000 was expended for fish. The value of the most important items imported from the United States is given in table 8.

TABLE 8.—*Most important imports to Puerto Rico from the United States for the fiscal year ending June 30, 1939* [1]

Article	Value	Article	Value
Rice	$5,466,216	Lard, fat, and oils (edible)	$2,381,736
Cotton cloth	5,292,813	Electrical machinery and apparatus	1,998,305
Iron and steel manufactures	4,838,742	Silk manufactures	1,950,952
Cigarettes	3,491,023	Soap and toilet preparations	1,652,820
Meat products	3,442,501	Paper and manufactures	1,526,952
Leather manufactures (mostly shoes)	3,214,326	Cotton wearing apparel	1,468,182
Automobiles and other vehicles	2,827,406	Wheat flour	1,437,882
Lumber and wood products	2,805,340	Dairy products	1,344,463
Rayon and other synthetic fabrics	2,611,164	Fertilizers and fertilizer materials	1,328,755
Petroleum and products	2,535,032	Dried beans	1,327,670
Industrial machinery	2,415,740		

[1] Data taken from the following publication: DIVISION OF STATISTICS. DEPARTMENT OF AGRICULTURE AND COMMERCE. ANNUAL BOOK ON STATISTICS, FISCAL YEAR 1938-39. 222 pp. [1939]

In 1935 only five countries—United Kingdom, Canada, Japan, France, Germany—in addition to the Territory of Hawaii, bought more goods from the United States than did Puerto Rico.

Puerto Rico's position in United States trade is shown in table 9, taken from data of the United States Department of Commerce.

TABLE 9.—*Puerto Rico's place in export and import trade with the United States* [1]

[In thousands of dollars—i. e. 000 omitted]

Country	From the United States in—			To the United States in—		
	1935	1936	1937	1935	1936	1937
United Kingdom	$433,399	$440,122	$534,564	$155,282	$200,385	$202,771
Canada	323,194	384,151	509,508	286,444	375,832	398,539
Japan	203,283	204,348	288,378	152,902	171,744	204,202
France	117,013	129,457	164,211	58,107	65,288	75,663
Germany	91,981	101,956	124,166	77,792	79,679	92,644
Hawaii	78,925	85,744	104,181	98,696	125,537	130,138
Puerto Rico	70,052	86,352	90,044	87,726	103,952	102,859
Cuba	60,139	67,421	92,283	104,303	127,475	148,047
Philippine Islands	52,640	60,350	85,031	96,999	101,679	126,207
Italy	72,416	58,989	76,792	38,674	40,337	48,188
Argentina	49,374	56,910	94,173	65,408	65,882	139,123
Brazil	43,618	49,019	68,631	99,685	102,004	120,639
British Malaya	4,500	5,021	8,834	131,607	167,997	235,194

[1] From U. S. Department of Commerce, Summary of United States Trade with World, 1937, except data on Puerto Rico and Hawaii, which are from Monthly Summary of Foreign Commerce of the United States, December 1937.

According to the Annual Book on Statistics (1938–39) of the insular government, Puerto Rico exported a total of $86,486,570 worth of merchandise in the fiscal year 1939, of which $84,782,650 worth went to the United States (table 10). Of this amount $53,604,381 was for sugar. In 1936, Puerto Rico ranked seventh (table 9) among the countries shipping goods to the United States. The island led such countries as Brazil, Philippine Islands, Argentina, France, and China, but was led by Canada, United Kingdom, Japan, British Malaya, Cuba, and Hawaii. The percentage of Puerto Rico's world commerce that has been shared with the United States has ranged from 17.8 percent in 1896 to 95.3 percent in 1936.

TABLE 10.—*Value of shipments of most important merchandise from Puerto Rico to the United States in the fiscal year 1939* [1]

Product	Value	Total value	Product	Value	Total value
Sugar		$53,604,381	Oranges	$2,041	
Unrefined	$44,251,614		Pineapples	862,423	
Refined	9,352,767		Other fresh fruits	1,497	
Cotton manufactures		9,511,472	Prepared or preserved:		
Tobacco and manufactures		7,464,394	Grapefruit	170,466	
Unmanufactured:			Pineapples	142,533	
Leaf, stemmed	6,355,627		Other prepared or preserved fruits	15,507	
Leaf, unstemmed	217,868		Orange peel	1,147	
Stems, scrap, and trimmings	825,119		Linen manufactures		$2,605,893
Manufactured:			Alcohol		393,504
Cigars and cheroots	37,602		Coconuts in the shell		306,021
Cigarettes	26,985		Coffee		475,316
Other tobacco manufactures	1,193		For export	407,771	
Molasses		565,699	For consumption	67,545	
Fruits		1,352,609	Silk manufactures		2,661,282
Fresh:			Rum		3,194,849
Citrons	6,872		Buttons, pearl or shell		303,145
Grapefruit	110,612		Straw hats		235,634

[1] See footnote 15, p. 67

According to the 1935 census of the Puerto Rico Reconstruction Administration, the leading enterprises, based on agriculture, and the number of persons employed in them are as follows: Cigar and tobacco

factories, 14,712; sugarcane mills, 16,162; and other food industries, 4,737. Agriculture employs 246,976 persons. The number of people, mostly women and girls, employed in the clothing and embroidery shops, is 19,857, and needlework and embroidery is done in the home by 50,371 persons. Although these are not agricultural industries, a large number of the employees are from the rural districts, as the farm women do piece work in their homes. The towns employing the largest number of employees are Mayagüez, San Juan, Ponce, and Arecibo.

On the farms visited by officials of the Division of Labor during 1930–31, a total of 30,714 persons were employed on sugarcane plantations, 5,851 on coffee plantations, and 5,202 on tobacco plantations. Wages are higher in the sugar mills and fruit industries than in the coffee or tobacco shops. Wages in the embroidery and needlework shops are slightly less than in the cigar factories. Wages range from 50 cents to $3 a day in the fruit industries and from 12 cents to $1.70 a day for women in the embroidery and needlework shops.

The farm land and buildings were assessed at $156,278,450 in 1935. Fifteen percent of the farms operated by full owners were mortgaged for $13,323,869, or 49.9 percent of their assessed value of $26,981,893. The public debt of the island is high; on June 30, 1933, it was $47,587,-616.76, of which $17,872,122.22 was municipal debt and $29,715,494.54 was insular debt.

SUGARCANE (CAÑA DE AZÚCAR)

Sugarcane is the most valuable crop, and the manufacturing of refined and raw sugar is the most important industry. The climate, soil, and people are adapted to the production of this crop. It might be said that Puerto Rico is a sugar-bowl island, as nearly $54,000,000 of the $86,486,570 obtained for total exports in 1938–39 was from sugar, molasses, and alcohol. Generally speaking the yield and price of sugarcane is the barometer of prosperity for the entire island.

Sugarcane was first brought to the island from Haiti in 1515 (*16, p. 795*). For the first 32 years molasses only was manufactured. The first muscovado mill for the manufacture of sugar was built near Bayamón in 1548 (*17, p. 541*). At that time sugarcane was grown on the alluvial soils along the rivers Bayamón and La Plata. These soils are still producing sugarcane after more than 380 years of cultivation. They are now producing a higher tonnage than ever before, due to excellent varieties, good management, constant control of diseases and insects, fertilizer, and some irrigation. From all indications these soils will continue to produce good crops, if intelligently managed, for hundreds of years.

Many fluctuations have taken place in the industry since 1515. At one time in the seventeenth century, ginger was cultivated, almost to the exclusion of sugarcane. Later a royal decree prohibited the growing of ginger, and through governmental aid the sugar industry was established.

The production (*16, p. 795*) of sugar in 1581 was about 187 tons, and in 1828 [15] it had increased to 9,391 tons. For the next 20 years, there was a gradual increase to 52,089 tons in 1847. During the following 20 years, the production varied between 43,195 and 65,517 tons. In

[15] The Annual Book on Statistics for 1939-40 gives the yearly production of sugarcane from 1828 to 1939.

1879, a peak of 170,679 tons was reached. This high production was not exceeded until 1905, when 214,480 tons were produced. Since then, the yearly production has never been below 200,000 tons. In 1920, 485,077 tons were produced. With slight variations, production increased yearly until 1934, when an all-time peak of 1,103,822 tons was reached. Partly due to curtailment of the acreage, only 773,021 tons were produced in 1935, but an increase to 851,969 tons was made in 1939. The production in 1934 was almost one-half as great as that of Cuba and about 6 percent of the world production; in 1939 it was less than one-third of that of Cuba and 4.1 percent of the world production.

The value of exported sugar also has varied in different years, according to the amount exported and the price per ton. The value of the export sugar increased from $4,715,611 in 1901 to a high of $98,923,750 in 1920. The value fell to $35,224,038 in 1929 but increased to $53,604,381 in 1939. In 1935, sugar to the value of $47,837,144 was exported. Between 1901 and 1935 the price of exported sugar has ranged from $3.02 to $11.79 per 100 pounds. The price in 1939 was $2.84, the lowest yet recorded.

The number of sugar mills has varied considerably. In 1581, only 11 were reported on the island, but in 1879, 553 were grinding sugarcane (*16, p. 795*). In 1910 there were 41 modern mills, 14 old steam mills, and 91 ox mills grinding cane (*2, p. 15*). At present about 40 mills manufacture all the sugar produced on the island. In remote areas a few ox mills are still in use for grinding the sugarcane for locally used molasses.

According to the Puerto Rico Reconstruction Administration census of 1935 (*34*), the acreage in sugarcane has increased from 145,433 cuerdas in 1909 to 245,154 cuerdas, or 34.5 percent of the land from which crops were harvested, in 1935. This crop occupies a larger total area than any other crop grown on the island.

Figure 37 shows the distribution of sugarcane as recorded by the Puerto Rico Reconstruction Administration census of 1935. It may readily be seen that most of the sugarcane grows in the municipalities bordering the coast. The best soils for the production of sugarcane, such as those on the nearly level flood plains, terraces, and alluvial fans, occur within these municipalities. Owing to the good soils and valuable crops, roads, railroads, and towns are numerous along the coast. The production of sugarcane is limited largely to areas within a kilometer of a good road or railroad. Although sugarcane is grown throughout most of the island, unless the land is irrigated it is not grown on level areas receiving less than 40 inches of mean annual rainfall or on very steep land receiving less than 60 inches. In humid districts, much cane is grown on hills having 50-percent slopes. The municipalities having the largest acreage in sugarcane, ranking in the order named, are: Arecibo, Juana Díaz, Cabo Rojo, Loíza, Lajas, San Germán, Naguabo, Ponce, Guayama, and Salinas. In these municipalities the percentage of total crop land in sugarcane ranged from about 33 percent in Arecibo to 75 percent in Salinas. It is interesting to note that the acre yield is only three-fourths as great in the municipality of Arecibo as in the municipality of Santa Isabel. Most of the soils used for cane in the latter municipality are those of the San Antón, Santa Isabel, Fraternidad, and Aguirre series. In the Arecibo municipality cane is grown on less productive soils, such as

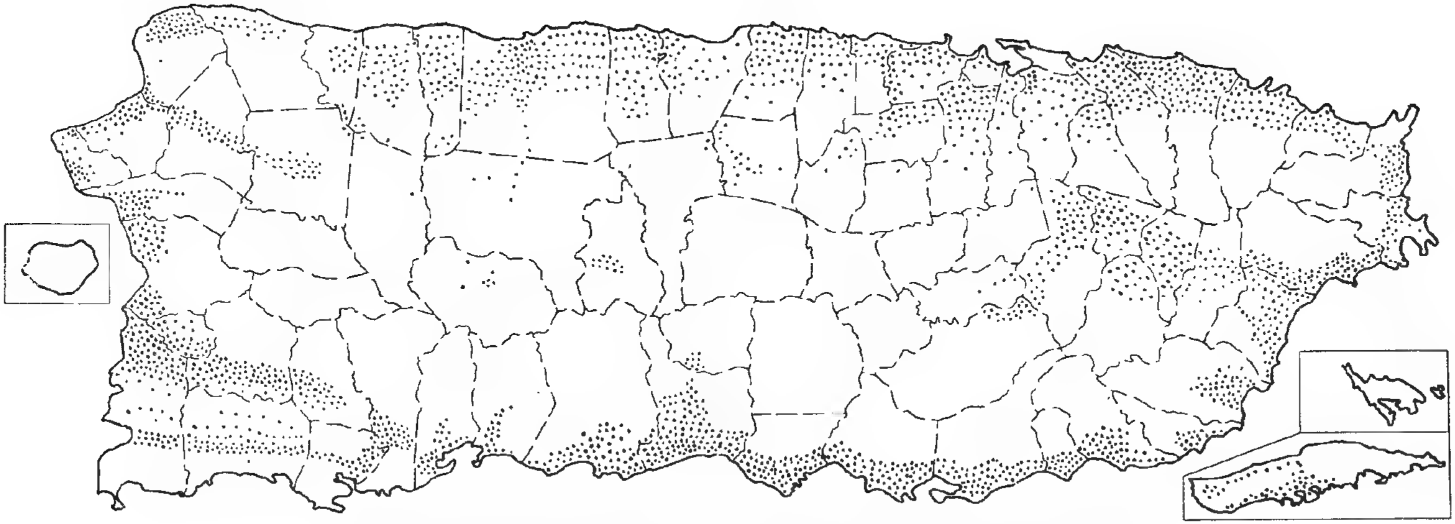

FIGURE 37.—Distribution of sugarcane in 1935. Each dot represents 100 acres.
Distribución de caña de azúcar en 1935. Cada punto representa 100 acres.

the Bayamón, Vega Alta, Sabana Seca, Espinosa, Coloso, and Toa.[16] Soils of the Coloso and Toa series are the most productive for sugarcane on the north coast, but they do not return such high yields as does the best soil along the irrigated southern coast.

Field observations and factory figures indicate that a higher yield of both sugar and sugarcane is obtained on the irrigated south coast than in any other large area on the island. This is because the low relative humidity along the south coast and a sufficiently regulated irrigation water supply, combined with level, deep, well-drained alkaline soils, make most favorable conditions for the growth of sugarcane. In addition, the soils have not been leached of mineral elements to so great an extent as have those in the areas of higher rainfall. Most of the soils of the south coast have been farmed for less than 40 years

FIGURE 38.—Excellent sugarcane.
Caña excelente.

whereas those in other parts of the island have been under cultivation nearly 400 years.

The best soils along the south coast, under favorable conditions and proper management, produce from 80 to 100 tons of sugarcane an acre, or from 10 to 14 tons of sugar (fig. 38). Here, some of the best land sells at prices ranging from $600 to $700 an acre. On the north coast the best land sells at prices ranging from $350 to $400 an acre, and a few irrigated areas sell for about $500 an acre.

Most of the land used for the production of sugarcane either is planted to this crop or is in process of preparation for it. The two planting periods are: Fall planting, or gran cultura, which is from July to November; and spring planting, or primavera, which is from January to June. Gran cultura crops grow for a period ranging from 14 to 22 months, averaging about 16 months, and primavera crops

[16] The soil series and soil types are defined in the section entitled "Soils and Crops."

mature within about 13 months. Both plantings will continue to produce volunteer, or ratoon, 12-month crops year after year, or until the fields are plowed. The tendency in the last few years is to give the sugarcane as long a period of growth as possible—that is, long ratoons and fall plantings rather than primavera plantings.

As gran cultura crops are planted in the rainy summer months and have a long period of growth, they outyield primavera crops by 15 or 20 percent. Usually primavera crops outyield the first ratoon crop by 10 or 15 percent. The succeeding ratoon crop yields from 5 to 10 percent less than the previous ratoon crop.

FIGURE 39.—The chimney—all that remains of an abandoned small sugar mill. La chimenea—todo lo que queda de una pequeña central abandonada.

The proportion of each of these types of planting to the total area planted varies in different parts of the island and with the individual grower. In general, the farmers having a small acreage of sugarcane have a much larger percentage of their land in 2-, 3-, or 4-year ratoon crops than the large-scale operators. The sugar centrals on the south coast have a higher percentage of gran cultura plantings than those in any other part of the island. Along the south coast during average years, about 25 percent of the land is in gran cultura, about 35 percent is in primavera, and about 40 percent is in ratoons.

On the level coastal plains, on such permeable soils as the Bayamón, Espinosa, Vega Alta, Coto, and Matanzas, the general practice is to grow a large proportion of ratoons and very little primavera plantings. In Isla de Vieques and semiarid districts, where the tonnage is low and very little fertilizer is used, five or six ratoon crops are common.

The sugarcane grower is interested primarily in obtaining the greatest acre yield of sugar at the lowest cost. Two of the most important factors in reaching this objective are efficient management and land suited to the growing of sugarcane. Efficient management includes efficiency in the sugar mills as well as in the canefields, and efficiency in the mills has increased manyfold since the time of small muscovado mills. In order to compete with other sugarcane-growing countries the small mills were abandoned (fig. 39), and large central mills were constructed (fig. 36). Each of the latter will grind the same quantity of sugarcane formerly ground by about 20 small mills in less than one-half of the time and with an increased sugar yield of more than 50 percent. The modern sugar-central factory is now developed

to a fine degree of perfection. The grinding capacity of the mills has increased from a season's grinding ranging from 20 to 1,000 tons of sugarcane in the first small mills to the 24-hour grinding capacity ranging from 1,000 to 4,000 tons in the present-day up-to-date mills.

Most of the canefields of the large sugar centrals are scientifically managed. They seem to be properly fertilized,[17] cultivated, and drained or irrigated if necessary. Excellent sugarcane varieties are grown, and continuous effort is being made to combat harmful insects, diseases, and weeds. Many of the owners of small sugarcane farms are not financially able to weed, fertilize, or manage their fields in the most efficient manner.

In order to compete successfully with the world's sugarcane-producing countries, Puerto Rico must economically produce a very high tonnage to the acre. The best way to do this seems to be on a

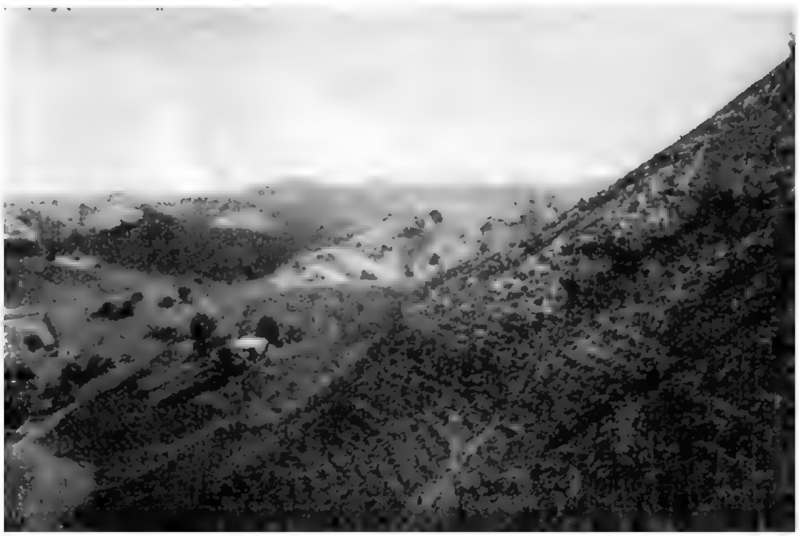

FIGURE 40.—Múcara silty clay loam on steep hillsides, used for the production of sugarcane. Yields are less than 18 tons an acre.

Laderas escarpadas de Múcara limo-arcilloso lómico sembradas de caña. El rendimiento es menos de 18 toneladas por acre.

large-scale production, with sufficient capital to invest in large quantities of fertilizer, machinery, and irrigation if necessary. Sufficient and contented labor at the proper time is another prerequisite for success in the sugar business.

Sugarcane can be grown successfully on many soil types, ranging from calcareous friable fine sandy loams to acid plastic clays and from medium-shallow steep soils of the uplands to the deep well-drained and poorly drained level soils of the river flood plains. Even the organic soils of the coastal lowlands produce fair yields, if the areas are well drained and fertilized. The acre yields, however, range from about 15 tons on the poorest soils (fig. 40) to more than 100 tons on the best soils, and the profits vary somewhat accordingly. According to Jensen

[17] Many of the large sugar centrals have their own scientifically planned fertilizer experiments and variety test plots on several of their most important soil types.

(*21, p. 32*), more than 50 percent of the sugarcane roots on dry-weight basis are in the first 8 inches of the soil, but sugarcane growing on soil having a depth ranging from 12 to 18 inches, such as the Múcara, Juncos, and some soils of the Colinas series, produce far lower yields than sugarcane produced on related but deeper soils, such as those of the Mabí, Santa Clara, and Camagüey series. The extensive development of the root system depends on the physical and chemical condition of the soil types, and without a healthy, well-developed root system the normal functions of the entire plant cannot operate at maximum efficiency.

The best land for sugarcane in Puerto Rico has a friable loam or silt loam surface soil, high in organic matter, neutral or alkaline in reaction, brown or very dark grayish brown, free from gravel or harmful salt, and granular, with a slightly heavier but friable alkaline subsoil beginning at a depth of 10 or 12 inches and continuing to a depth below 5 feet before any free water or gravel is reached. The surface soil is loose and porous and when cultivated forms an ideal seedbed. It can be worked under a fairly wide range of moisture conditions without harming its structure. The subsoil has enough silt and clay to prevent serious leaching of fertilizers or lime, yet it is not too heavy to interfere with the rapid penetration of roots. Water penetrates this soil rapidly and does not remain on the surface for any length of time. Owing to the slightly heavy subsoil, a high proportion of the percolating water reaching it is retained and is utilized by the lower roots of the cane. Soils of this description generally are flat. They allow the use of most kinds of modern machinery, and they are almost ideal for maximum agricultural utilization. Typical areas of Altura loam, Altura silt loam, San Antón loam, and San Antón silt loam have these characteristics, and when they are fertilized with from 300 to 400 pounds of mixed fertilizer and 300 to 400 pounds of ammonium sulfate, are properly managed, and have sufficient water, sugarcane will yield from 75 to 110 tons to the acre. Some of the other good soils for sugarcane on the south coast are those of the Machete, Fraternidad, Santa Isabel, Paso Seco, Vives, Coamo, Aguirre, and Guánica series. These soils have an acre yield ranging from 40 to 85 tons of gran cultura. The Ponceña, Moca, Dominguito, and Las Piedras soils occurring in the inner plains also are good soils for sugarcane. Most of the sugarcane on the north and west coasts is grown on the well-drained alluvial Toa and Estación soils, the imperfectly drained Coloso soils, and the poorly drained Palmas Altas soils. These soils when properly managed and planted to gran cultura yield from 40 to 60 tons to the acre. The yield of cane depends to a large extent on the management, fertilizer used, and especially the amount of rainfall during the critical period of ripening which, according to Davis (*15, p. 3*), is between December and February. The Coloso soils in the vicinity of Cabo Rojo and Filial Amor seem to be much more productive than the Coloso soils near Central Coloso or along the north coast. The difference in yields for the same soil in different parts of the island may be due to better management, more rainfall at the proper time, or to the fact that the soils have not been under cultivation for so long a time near Cabo Rojo as they have along the north coast.

A large acreage of the nearly level areas of such soils as Coto, Bayamón, Vega Alta, and associated soils in the northwestern part are in sugarcane. These soils produce from 20 to 45 tons of gran

cultura cane when they are properly managed. In the eastern end the best soils for the production of cane are those of the Fortuna, Viví, Yabucoa, Josefa, and Maunabo series. When these soils are planted to gran cultura and properly managed they produce from 30 to 50 tons to the acre. The interior hill lands, such as the Múcara, Alonso, Catalina, Río Piedras, Cayaguá, Utuado, and Colinas soils, produce from 18 to 30 tons of gran cultura. They require nearly as much fertilizer and weeding as do the soils producing 100 tons to the acre. It may readily be seen that the greatest profit is made from the cane grown on the best soils.

Such soils as the Nipe, Rosario, Tanamá, Pandura, Teja, Picacho, Yunes, Aguilita, San Germán, Descalabrado, Jácana, Guayabo, Corozo, Algarrobo, St. Lucie, Cataño, Meros, and Jaucas, the steep

FIGURE 41.—Plowing land for sugarcane with oxen. Note how the yokes are attached to the animal's poll and forehead.

Arando con bueyes. Nótese los yugos en los animales.

phase of Soller, and coastal beach are not adapted to the production of a very high tonnage of sugarcane.

The Nipe and Rosario soils lack plant nutrients, and the Rosario soils are too steep for cultivation, as also are the Tanamá soils and most areas of the Pandura soils. The Pandura and Teja soils are low in fertility and are droughty. The Picacho and Yunes are too shallow and steep for the production of cane. The Aguilita, San Germán, Descalabrado, and Jácana occur in too dry a climate for the production of cane without irrigation, and the relief of these soils is unfavorable for irrigation. All except the Jácana soils are very shallow. The very sandy soils are too loose and low in fertility for profitable yields of sugarcane.

The method of planting and cultivating sugarcane varies considerably for soils having greatly contrasting characteristics. The clay soils are handled differently from the sandy soils, and the soils on steep hillsides are planted differently from those on level land. Poorly drained soils require more attention than well-drained soils. In

general the heavy-textured soils of the level river flood plains, alluvial fans, terraces, and inner plains are plowed twice, to a depth ranging from 12 to 18 inches. One plowing is at right angles to the other, and the land is harrowed after each plowing. At present more of the plowing of the large tracts is done by tractors than formerly. The use of tractors enables land to be in sugarcane that otherwise would be in pasture and hay for the work oxen. Most of the small farm owners still use oxen (fig. 41) and all plowing on hillsides and poorly drained areas is done by oxen. The rather steep hillsides, the permeable clay soils of the uplands, the coastal plains, and the sandy-textured soils are plowed only once. In some areas near the rivers the alluvial soils that are subject to overflow are not plowed at all, but furrows are made in which the sugarcane cuttings are planted.

FIGURE 42.—A cable-gear plow making furrows in the soils of the alluvial fans along the irrigated south coast. Cane cuttings 10 or 12 inches long will be placed in the furrows and covered to a slight depth.

Haciendo surcos en los aluviones bajo riego de la costa sur para sembrar pedazos de caña de 10 ó 12 pulgadas de largo.

Within the last few years a specially constructed rotating plow—the gyrotiller—has been used. Foss (*18, p. 81*) states that, in 1935, 13 of these were in operation on the island. This plow does exceptionally good work in the churning of the soil to any desired depth not exceeding 2 feet. The soil is well churned and aerated yet not changed in position. This type of plowing should be very beneficial for those soils having heavy nearly impervious subsoils, such as the Sabana Seca, Santa Isabel, and Candelero soils, and the heavy-subsoil phases of the Vega Alta soils. Two sizes of gyrotiller are in use. The larger weighs 24 tons and has a 170-horsepower Diesel motor, and the smaller weighs 12 tons and has an 80-horsepower Diesel motor. The larger machine has an 11-foot plow width and the smaller one a 9-foot width. The cost of plowing with these machines ranges from $4 to $5 an acre. Other plows and tractors seen in many of the sugarcane fields are the large steam cable-gear plows (fig. 42) and various types of caterpillars.

On some of the heavy clay soils having compact subsoils, deep knifing or deep subsoiling is beneficial. This is a costly operation,

however, and should be practiced only in soils that will not run together after the first few rains. Such soils as those of the Santa Isabel, Sabana Seca, Candelero, and similar series are greatly benefited by such treatment. Such plastic soils as those of the Aguirre, Ponceña, Camagüey, Coloso, and similar series would be benefited for a short time only. Shallow knifing has proved beneficial on some of the shallow hill-land soils, such as the Múcara and Teja.

After the land is plowed and harrowed, it is ready to be planted. The sugarcane is planted either in furrows about 4 feet apart, in grand bank, or in shallow holes 4 feet apart. On the well-drained river flood plains soils, such as the San Antón, Toa, and Viví, and on the alluvial fans and terraces, both in the irrigated arid districts and in the humid districts, the sugarcane is planted in furrows. In the humid districts, drainage ditches are dug at intervals of about every 10 rows, and they are usually dry except during long wet periods. In the dry nonirrigated districts the furrows are deeper than in irrigated or humid areas, because it is necessary to plant the cuttings deep enough that they will be in an environment that is sufficiently moist to start germination. As the roots continue to grow to greater depth, they have, during droughts, a much larger area to drain than if the cuttings were planted at a slight depth.

On some of the deep upland soils, such as the Catalina, Cialitos, and Alonso, sugarcane often is planted in shallow holes 4 feet square and several sugarcane seed pieces are placed in each hole. The holes are not entirely filled with earth when the seed is planted, and they act as catch basins for sheet-erosion waters and help considerably in checking the speed and force of the flowing water. After sugarcane becomes a foot or more high, it is a fairly good crop for checking sheet erosion, even on steep hillsides.

Sugarcane seed for gran cultura planting is obtained from selected fields of young sugarcane stalks, about 8 months old, that are free from mosaic. Ratoon cane makes desirable seed. The sugarcane stalks are cut in pieces from 9 to 12 inches long, and they usually have two internodes and three nodes, or buds. Generally the leaf sheath is removed, except when the planting is made in sandy soils that are infested by the mole cricket, or changa. From 1½ to 3 tons of cuttings are required to seed an acre. The price of this seed ranges from \$4 to \$10 a ton, and the average price is about \$7. Seed for primavera plantings is much less expensive, as this seed is obtained from a point near the tops of matured sugarcane stalks during harvest. The upper parts of the stalks contain every little sucrose; consequently they are of little value when ground for sugar. Cane seed of this kind sells at prices ranging from \$2.50 to \$4 a ton.

All the sugarcane is planted by hand. When planted in furrows, the seed cuttings are spaced from 6 to 12 inches apart in the bottom of the furrows in a single row, and one end of the cutting is covered with a few inches of soil. Some farmers plant two rows of cuttings about 4 inches apart in the bottom of the furrow and space the cuttings from 14 to 18 inches apart. In some parts of the island, as near Fajardo, entire sugarcane stalks are placed end to end in the bottom of the furrow and covered with a few inches of soil. The advantage of this method is (often) better germination and less opportunity for infestation by disease germs which may be on the cut

surfaces of the seed pieces. In the poorly drained river flood plains and coastal lowlands, on such soils as those of the Coloso, Fortuna, Palmas Altas, Aguirre, Yabucoa, and similar series, sugarcane is planted in grand banks. With this system of planting a ditch is dug on each side of every two, three, or four rows, depending on the amount of water to be drained away (fig. 43). Deeper cross ditches are dug at intervals ranging from about 20 to 40 feet. These ditches lead to larger drainage ditches and finally to the rivers. Most of the ditches are dug by hand, but some are made with a No. 90 plow. They are cleaned with a double moldboard plow or by hand. It is essential that the ditches be maintained at all times, in order to prevent the soils from becoming waterlogged. During long protracted droughts, the ditches can be blocked and the water table can be regulated to the best advantage of the growing crop. As lack of

FIGURE 43.—A modified grand-bank method of planting sugarcane on Coloso silty clay. None of the ditches is very deep.

Método de gran banco modificado en Coloso limo-arcilloso. Las zanjas no son muy profundas.

water is not a limiting factor on soils that are planted according to the grand-bank system, the sugarcane cuttings are planted in shallow holes.

The muck and peat areas planted to sugarcane require more complex drainage systems than do the mineral soils; in many places pumps are installed and dikes are built, in addition to the ditches necessary for the grand banks. This is because most of the muck and peat areas are slightly below the level of high tide.

In the permeable well-drained valley coastal plain soils, such as the Espinosa, Coto, Matanzas, Bayamón, and Vega Alta, sugarcane is planted in furrows, generally following the contour of the land, especially in the irrigated districts near Isabela. These soils are not only so permeable that drainage ditches are unnecessary, but in many areas lack of water is a limiting factor in crop production, and it is essential that the sugarcane cuttings be planted in furrows ranging from 10 to 15 inches in depth.

On the inner plains in such plastic soils as the Camagüey, Santa Clara, Ponceña, Moca, Mabí, and associated soils, sugarcane is planted in shallow furrows, although shallow drainage ditches are numerous. The naturally rolling relief is a very desirable feature for these soils, as a large proportion of the excess water is drained from the surface. In the few nearly level areas of these soils it is difficult to drain the land properly so that the sugarcane cuttings will germinate and develop a good root system. The character of the sticky plastic subsoil prevents excess water from percolating through it as fast as it should or as fast as the water penetrates the plastic but not so sticky poorly drained soils of the coastal lowlands and river flood plains. The drainage ditches, made either by hand labor or machines, are much more expensive than those made on other soils, because the soil sticks to shovels, plows, and other implements. Laborers refuse to work in this soil at the same price as in other lands, because of the harder and slower work.

On the medium deep soils of the uplands, such as those of the Juncos, Múcara, Río Piedras, Colinas, Cayaguá, and similar series, the progressive landowners use contour furrows, with numerous drainage ditches running zigzag down the hill. The bottoms of the ditches generally rest on rocks, so that gully erosion is arrested and does very little damage.

When the land is prepared for grand-bank plantings, from two to four pieces of sugarcane cuttings are planted on the banks in holes about 18 inches square and 6 inches deep. The holes are spaced from 40 to 60 inches apart, or about 2,000 to an acre. The seed pieces are planted by hand with a short-handled pick or hoe, and they are so placed in the ground that about one-half of the seed is exposed at an angle of about 30°.

The principal sugarcane varieties grown vary considerably in different parts of the island and on different soil types. B. H. 10 (12) is the dominant variety grown on soils of the river flood plains, such as the Toa, San Antón, Coloso, Yabucoa, Viví, and similar soils, regardless of the location or climate. If the sugarcane becomes badly infected with mosaic, however, the acreage of B. H. 10 (12) is reduced and that of P. O. J. 2878 and Mayagüez 28 is increased. P. O. J. 2878 is probably the second most commonly grown variety on these soils. A much higher proportion of this variety, however, is grown on the north coast than on the south coast. P. O. J. 2725 and P. O. J. 2878 are the principal varieties grown on the level permeable acid coastal plains, on such soils as those of the Vega Alta, Espinosa, Bayamón, and related series. Mayagüez 28 seems promising for these soils. P. O. J. 2878, B. H. 10 (12), and S. C. 12/4 seem to be the main varieties grown on the soils of the uplands, such as the Catalina, Colinas, Soller, and Múcara. Uba and S. C. 12/4 are the principal varieties grown in arid nonirrigated districts and by the owners of small tracts of land. In the northeastern part of the island probably 85 percent of the land in cane is planted to B. H. 10 (12) with S. C. 12/4, F. C. 916, and P. O. J. 2878 occupying most of the remaining 15 percent. In this area the average sucrose content is about 18 percent, the purity about 83 percent, and the yield about 11.5 percent. The number of tons of sugarcane produced to the acre in this area and on the alluvial soils of the north coast is about 31. Gran cultura averages about 40 tons, primavera about 35, and ratoons about 28. In this

area B. H. 10 (12) outyields S. C. 12/4 by about 10 tons to the acre. On the south coast on irrigated lands gran cultura averages about 65 tons, primavera about 42, and ratoons about 35. On the northwestern coastal plains the gran cultura plantings yield about 40 tons, the primavera 30, and the ratoons 25. In arid nonirrigated districts, such as on Isla de Vieques, most of the cane is ratoon S. C. 12/4, which yields from 15 to 25 tons to the acre.

Very little machinery is used in cultivation of the growing cane. The ratoon cane is plowed with a walking single moldboard plow, usually pulled by a mule. The plowing of the ratoons generally is completed within 2 weeks after harvest. First, the cane trash, or paja, is laid in alternating furrows by hand, the clean bank is then cultivated, and the trash is placed in the plowed furrow. The other row is plowed. During the plowing dead plants are replaced by new seed. In some fields that have been ratooned for many years, most of the growing cane consists of replants. The trash is burned in irrigation districts, in order to have unobstructed watercourses in irrigation. It is burned in many other areas also. Plowing is more difficult when the trash is not removed than when it is burned. Trash is usually burned in all areas subject to frequent overflow, as, if allowed to remain in the fields, it may be carried by floodwaters and piled on young cane, thereby killing the plants.

Almost all the weeding is by hand labor. Usually it is necessary to weed the cane several times before the plants are large enough to shade the ground and naturally keep the weeds under control. Some varieties of cane are far superior to others in this respect. Mayagüez 28 stools prolifically, and the cost of cultivation is much less than that of the erect canes with few stools.

Experiments with different fertilizer formulas seem to indicate that all the soils need a large quantity of nitrogen, less potash, and a small quantity of phosphorus. The red acid soils of the uplands probably need a larger quantity of phosphorus than the soils in the arid districts or the alluvial soils along the north coast. In most of the experiments with sugarcane, an application of phosphoric acid in excess of 90 pounds to the cuerda apparently lowered the gain in yields. The more common applications range from 150 to 250 pounds of ammonia to the acre, 30 to 90 pounds of phosphoric acid, and 100 to 200 pounds of potash. Fertilizer formulas vary among the different landowners; the most commonly used formulas contain from 14 to 16 percent of nitrogen, 8 to 16 percent of potash, and 4 to 8 percent of phosphoric acid. From 400 to 800 pounds of mixed fertilizer is used to the acre, and from 400 to 600 pounds of ammonium sulfate is used as a second application. All the fertilizer is distributed by hand labor, generally by women. On most farms the complete fertilizer is spread within a radius of 8 inches of the cane plants, from 1 to 2 months after the sugarcane is planted. The second application (ammonium sulfate) is applied in the same way 2 months later. The fertilizers are covered with a one-horse plow or with hoes.

So much sulfate of ammonia has been applied to the soils that in the humid districts an application ranging from 2 to 4 tons of finely ground limestone has given good results, especially in soil having a pH value of 5.8 or lower. Bonnet (*9*) states that ammonium sulfate should not be used as a source of nitrate for plants on Lares clay loam. Extensive experimental work should be started on the effect of lime

and the availability of the essential plant elements in the different soil series. In some soils the effect of lime may make certain fertilizers less available and thus prove detrimental.

Cowpeas are the principal crop used for green manure in the sugarcane fields, but even they are used on only a very small proportion of the land. Cowpeas grow rapidly and readily on almost all of the soils, provided the rainfall is sufficient. In general the crop is ready to be turned under within 3 months from the time of germination.

Filter-press mud, or cachaza, is applied to the soils which produce poorly. Only a small quantity of this is available during the grinding season, and, as several tons are applied to the acre, only a small area is treated each year. Cachaza should be beneficial for land on which sugarcane is affected with chlorosis. Table 11 shows the composition of a composite sample of filter-press mud collected from January 22 to February 1, 1912, at the South Puerto Rico Sugar Co.'s plant and analyzed by their chemists.

TABLE 11.—*Chemical composition of filter-press mud, or cachaza*

Content	Percent	Content	Percent
Moisture	61.78	Ash	10.89
Organic	27.33	Phosphoric acid (P_2O_5), equivalent to bone phosphate, 3.95 percent	1.81
Wax	2.77	Silica (SiO_2)	.42
Ammonia (NH_3), equivalent to nitrogen (N) 0.774 percent	.94	Fe_2O_3 and Al_2O_3	1.70
Sucrose	3.86	Lime (CaO)	4.13
Invert sugar	(1)	Magnesia (MgO)	(1)
Undetermined	19.76	Undetermined	2.83

[1] Trace.

So little stable manure is available that practically none is used in the sugarcane fields.

The sugarcane is cut exclusively with a machete by hand labor (fig. 44). The peons are very proficient in this work; they can cut from 2 to 8 tons a day, depending on the quality of cane and the ambition of the laborer. Wages for this work range from 50 cents to $1.50

FIGURE 44.—Cutting sugarcane by hand in the eastern part of the island.
Cortando caña en la parte este de la isla.

a day or from 20 to 35 cents a ton of cane. After the cane is cut it is gathered immediately and usually is either loaded on oxcarts or cars on portable tracks and conveyed to a loading station where derricks are used to transfer it to railroad cane cars or trucks, and it is then hauled to the sugar central. Some centrals have the cane hauled directly from the field to the factory in oxcarts and in small cars (fig. 45) which hold from 1½ to 2½ tons and are run on portable tracks. Usually the portable tracks are connected with a network of permanent tracks leading to the factory. In a very few of the nearly inaccessible hill areas, such as near Central Soller and Central Plata, sugarcane is carried on horses and mules from the field to the factory. Cane is not carried by water or gravity as in some parts of Hawaii.

Sugarcane harvest extends from December to July, and during this period the factories run day and night with the exception of 1 day a week, which is devoted to the cleaning and repairing of machinery.

FIGURE 45.—Hauling sugarcane from the fields to the factory or to loading stations, where the cane will be transferred to larger cane cars.

Arrastre de caña de los campos a la factoría o a estaciones de carga para transferirla a vagones mayores.

During this season of the year, most of the laborers on the island obtain work, but during the rest of the year a high proportion of the sugarcane laborers are unemployed. Only a limited number of men obtain regular work in the canefields because weeding, ditching, and planting gran cultura cane is about the extent of the available work during the summer and early fall.

The pests and diseases most prevalent in the canefields are the sugarcane borer, white grub, mosaic, dry top rot, nematodes, yellow aphis, mole cricket, land crab, and rat. The sugarcane borer (*Diatraea saccharalis*) probably causes the greatest damage. It has spread throughout the island, but it is most damaging in gran cultura and primavera crops in the arid and semiarid districts. The white grub causes the greatest damage on the south coast but is also prevalent throughout the island. With the importation of the toad (*Bufo marinus*) and continued deep cultivation, the white grubs are not so

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abundant as formerly. Mosaic has been brought nearly under control by the use of mosaic-resistant varieties of cane and the continual roguing by all progressive landowners, as well as the selection of good mosaic-free seed. Dry top rot is most severe in the poorly drained lowlands, and for its control drainage is essential. Nematodes and other soil organisms cause a small amount of damage to the roots. The yellow aphis is more noticeable on poor soils in dry areas where the cane does not have the vitality to resist the attack of the sucking insects. The mole cricket is destructive in the loose sandy soils, such as those in the Isabela district. Partial control is effected by leaving the cane sheath attached to the cane seeds. Land crabs are destructive to young cane on the coastal lowland soils and poorly drained river flood plains. These pests are controlled with a poison mixture of corn meal and phosphorus placed on or near their holes. Rats do considerable damage near ditches along the coast.

Weeds are not a serious pest to any of the commercial crops. The principal weeds in the canefields are coquí, cadillo, abrojo, rabo de ratón, cohitre blanco, moriviví, and the more common grasses, such as Bermuda, cerrillo, grama blanca, and malojillo.

Irrigation of sugarcane is very similar to irrigation of corn in the semiarid section of continental United States. Laterals laid out with the contours of the land convey the water from the large canals to the growing plants. The source of water is from mountain streams that empty into fairly large reservoirs and from deep wells. The wells used on the south coast for irrigation range from 40 to 750 feet in depth. Most of the shallower wells are grouped in a series including from 4 to 10 wells, 6 inches each in diameter, connected to a centrifugal pump located near the center of the series, in a concrete pit ranging from 10 to 30 feet in depth. Many of the pumps are operated by electricity. The deep wells are about 20 inches in diameter, and in general each one is operated by a motor above ground. The ells on the north coast range from 60 to 300 feet in depth. Some farmers pump the water directly from the river stream. In the Isabela irrigation district all the irrigation water comes from Río Guajataca, and most of the main-line canal is lined with concrete slabs, owing to the porous character of the permeable clay soils traversed by the canal. Along the south coast, the only parts of the canals and laterals that are lined have a gravelly or rocky substratum near the surface.

In order to eliminate inefficient night irrigation, small overnight reservoirs have been constructed along the south coast and in the Isabela irrigation district. The reservoirs range in size from small circular basins 20 feet in diameter to cisterns 300 feet square and 10 feet deep.

The number of irrigations necessary varies with the season, soil, and plantings. Along the south coast, in the average alluvial soil, such as typical San Antón loam or San Antón silt loam, when the annual rainfall is about 45 inches, an 18-month gran cultura crop requires about 25 irrigations, or about 13 acre-feet of water. The primavera crops require about 8 acre-feet and the ratoons only about 6 acre-feet. In the Isabela district the permeable Coto clay and related soils require considerably more water than the soils along the south coast or the alluvial soils along the north coast. In most parts of the island the cane is watered as soon as it is planted and is rewatered in a week if the weather is dry. The frequency of irrigation from then until maturity

of the cane depends on the rainfall, but the average period between irrigations is 15 days.

When the cane becomes large, irrigation is very difficult, as it is hard for the irrigators to penetrate the canefields. Many of the lower leaves of the cane must be removed, in order that they will not interfere with the flowing water, and such a procedure also makes it easier for the men to penetrate the rank high cane.

The sugarcane industry in Puerto Rico is more important than any other of the main commercial crops. The island is naturally ideal for growing sugarcane. It has a favorable climate, good soil, and good transportation service to the United States. The laborers are accustomed to working either singly or in groups in the fields. They often have to walk several miles over steep mountainous trails to and from work, sometimes starting on their journey at 3 or 4 a. m.,

FIGURE 46. A modern sugar factory with well-managed fields of cane on good productive Toa soils. Note the bamboo along the streams.

Moderna factoría de azúcar con campos de caña bien administrados en suelos productivos Toa. Véase el bambú al borde de los ríos.

because work means food. The summer, or idle period, is the lean season for the laborer. However, very few men will work 6 days a week, even if they are paid by the day or by piece work. They like to start work on Tuesday and finish the week on Friday.

The Puerto Rican sugar growers, in order to counteract the competition of sugar growers in other countries, have enlarged their holdings for the purpose of more efficient management. The sugar industry requires large capital, either from individuals, corporations, or efficiently managed cooperative associations. To equip a modern mill, a capital between $1,000,000 and $2,000,000 is necessary. This includes railroads, livestock, field and factory machinery, and buildings.

It is unreasonable to expect a landowner to finance his small farm and also have a small sugar factory, but it is possible for an energetic owner of a small farm to plant and harvest a crop of cane and sell it at a cooperative mill or a sugar central, at a profit, provided he is able to have his cane ground at the proper time. His acre yield and profit will be much less than if the same land were operated by a more efficient landowner having a much larger holding. For the owner of a small farm to make a success it is essential that he obtain credit at a very low interest rate.

Most of the best land for sugarcane belongs to large corporations (fig. 46) or is leased by them. This land is very efficiently managed, and under the present economic conditions, with the protective tariff on sugar, such land in cane yields from 15 to 25 percent greater returns than if it were in the other commercial crops now commonly grown in Puerto Rico.

The acre yields on the better soils probably can be increased provided the sugar producers continue their scientific studies in search of better varieties, better fertilizer practices for specific soil types, more efficient machinery, and more effective control of insects and diseases. Additional irrigation, either by pumps or from streams also should increase the acre yield. Several areas, such as those near Rincón, Aguadilla, Añasco, Cabo Rojo, the east coast, and a narrow strip along the northern coast would be greatly benefited by some irrigation.

TOBACCO (TABACO)

According to Barrett (*6, p. 254*), tobacco (known to the Arawaks as cohoba) was widely cultivated in the Antilles long before they were discovered by the Spaniards. It was chewed, smoked, and taken as snuff by the aborigines. Dorsey (*16, p. 796*) states:

> Tobacco is indigenous to the island, but in the earlier years of settlement its cultivation was interdicted, both by papal bulls and royal decrees, the latter issued in 1608. However, its cultivation was permitted by a special law passed in 1614. By this same law the sale of tobacco to a foreigner was prohibited on penalty of death and confiscation of property. Other stringent measures were enacted in 1777 and 1784, which by their very severity defeated their own purpose. In 1775 the crop reached 701,750 pounds. Production was large enough to permit of exportation in 1836 (4,954,200 pounds), but by 1838 had declined to half that amount. The maximum crop was that of 1880, when 12,000,000 pounds were produced. The crop of 1897 reached 6,250,000 pounds.

According to the 1938–39 Annual Book on Statistics, the production between 1921 and 1939 has ranged between 50 million pounds in 1927 and 6 million pounds in 1932, and the acreage has ranged from 81,900 acres in 1927 to 10,079 in 1932. The price received by the farmers since 1921 has ranged from 39 cents a pound in 1926 to 11 cents a pound in 1938. The production reported by the 1935 census of the Puerto Rico Reconstruction Administration was 31,254,288 pounds (*34*), or slightly less than that produced in Georgia in 1934, according to the 1935 Federal census. The area in tobacco as reported by the 1935 census of the Puerto Rico Reconstruction Administration was 45,720 cuerdas, or 6.4 percent of the harvested cropland. This was considerably less than the total area in tobacco in Georgia. Production has dropped since 1934, as the Annual Book on Statistics reports an area of only 18,688 acres in tobacco and a production of 11,688,384 pounds in 1939.

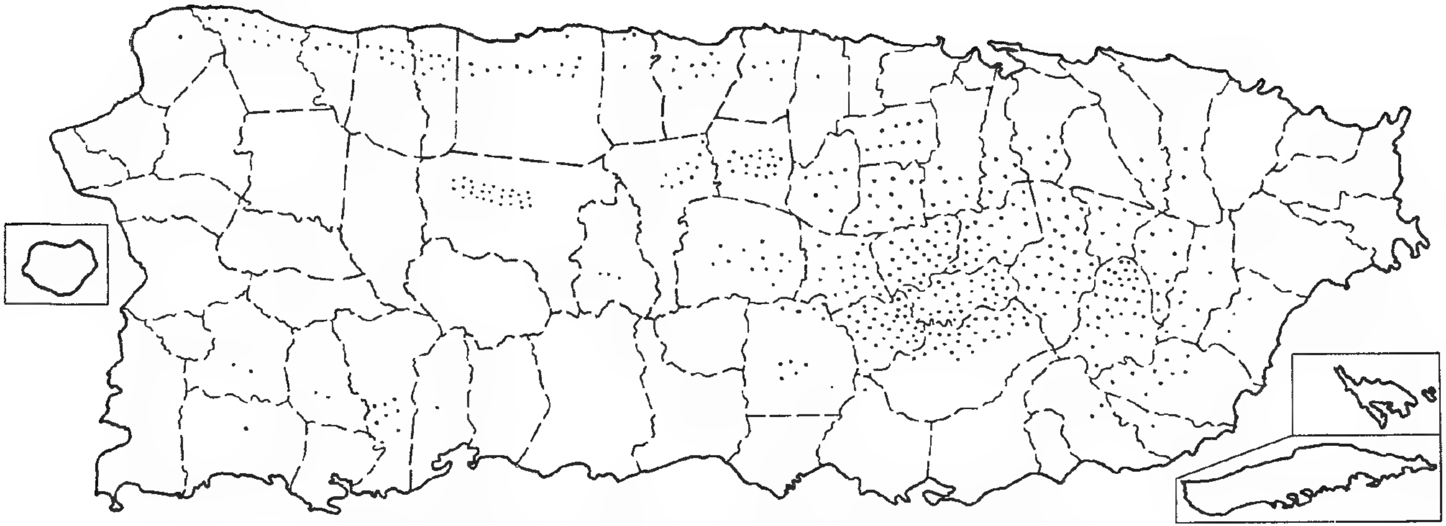

FIGURE 47.—Distribution of tobacco in 1935. Each dot represents 100 acres.
Distribución de tabaco en 1935. Cada punto representa 100 acres.

Between 1916 and 1931 the value of the export tobacco ranked second to that of sugarcane. Before 1916 it was exceeded by the value of both coffee and cane, and since 1932 it has been exceeded by cane and needlework. According to the Annual Book on Statistics (1938–39), $7,621,006 worth of tobacco was exported in the fiscal year 1939. Nearly the entire export crop is sent to the United States. Included in this total is $26,985 worth of cigarettes and $37,602 worth of cigars. The United States received all the cigarettes and almost all of the cigars. Puerto Rico imported $132,517 worth of leaf tobacco during the fiscal year 1939, nearly all of which came from the United States, with a small quantity from Cuba. During the same year, Puerto Rico imported $3,491,023 worth of cigarettes from the United States. The amount of money spent for imported cigarettes was more than one-third of the total export value of unmanufactured tobacco.

Compared with citrus or sugarcane, tobacco is a shallow-rooted crop. Therefore it will grow and produce fair or good yields on shallow

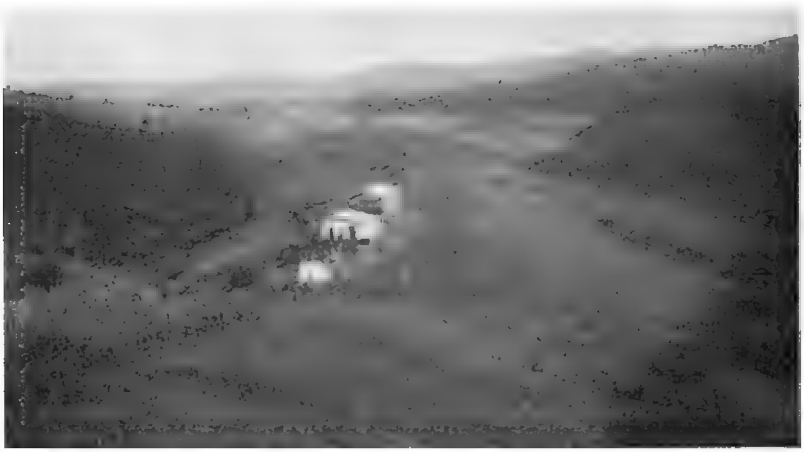

FIGURE 48.—Some of the soils used for tobacco near Cayey. The more rolling areas are Juncos clay, and the steeper areas are Múcara silty clay loam. In the foreground is a hurricane shed, a house, and a tobacco barn.

Algunos suelos sembrados de tabaco cerca de Cayey. Las areas más ondulantes son Juncos arcilloso, y las más escarpadas son Múcara limo-arcilloso lómico. Al frente, una tormentera, casa y rancho de tabaco.

soil or on steep hillsides. The best yields and quality are obtained on friable well-drained well-aerated soils that are neutral or alkaline in reaction, rich in plant nutrients, and situated at considerable distances from areas affected by the salt spray of the ocean. Tobacco is not well adapted to the strongly acid red soils of the uplands, as the acidity limits the supply of calcium and magnesium, as well as the availability of the phosphorus, and favors excessive solubility of aluminum and manganese. Areas of the Toa soils that are seldom overflowed are the most productive, but probably the largest acreages of tobacco are grown on the Múcara, Juncos, and related brown neutral soils of the uplands.

Figure 47 shows the distribution of the tobacco acreage in 1935, according to the Puerto Rico Reconstruction Administration census.

It may readily be seen that there are four tobacco areas. The heart of the largest is in the vicinity of Cayey. Tobacco in this area is grown mostly on the neutral friable rolling Juncos soils and on the neutral friable shallow very steep Múcara soils (fig. 48). To the east of Cayey tobacco is grown on the rolling granitic soils, among which the Las Piedras and Cayaguá are the most important (fig. 49). Northwest from Cayey considerable areas of Naranjito soils are used for the growing of tobacco. The best tobacco is produced in the vicinity of Cayey. The second most important area for the production of this crop is on the coastal plains in the vicinity of Isabela and eastward from that place to Vega Baja. The tobacco in the latter section is grown on the level or undulating soils derived from limestone, such as the Coto, Maleza, Vega Alta, and Bayamón soils and their shallow phases. All these soils occupy valleylike areas between limestone haystack hills. The third largest area is near Utuado, and the tobacco

FIGURE 49.—Cayaguá sandy clay loam near San Lorenzo, used mostly for the production of tobacco, corn, and beans.

Cayaguá areno-arcilloso lómico cerca de San Lorenzo usado principalmente para tabaco, máiz y habichuelas.

grown is good-quality cigar-filler tobacco. It is grown on the Utuado and Jayuya soils which are derived from granite. The fourth largest area is near Sabana Grande on nonirrigated semiarid lands, and the tobacco returns low yields. It is grown in small patches, generally on low slopes or in valleylike positions.

The procedure in growing tobacco is very similar to that followed in the United States. Carefully selected seed of healthy, vigorous, good-quality, adaptable varieties is first planted in well-prepared seedbeds, which, generally, are small, gardenlike, banked beds located on well-drained alluvial soils or on gentle slopes near the bases of the hills, where the soil is friable, well drained, and fairly high in organic matter—all requirements of a good seedbed. About 1 acre of a well-prepared and productive seedbed is required from which to plant from 130 to 140 acres. Selected seeds generally are planted under the protection of cheesecloth (fig. 50), which helps to protect the young, tender plants

from insects, intense direct sunlight, and the beating effect of dashing rains.

The first seeds are planted in the beds during August, and generally a second planting is made early in September. The seedbeds are well fertilized. The plants are transplanted to the field during the last of October, November, and the first of December. They should be well protected from the sun during transplanting. They are set from 12 to 15 inches apart in rows spaced from 36 to 44 inches apart on well-prepared, weed-free, well-drained soils. In nearly all of the fields on slopes ranging from 40 to 100 percent, shallow ditches are dug around every plot (which includes about 900 square feet), giving the field the

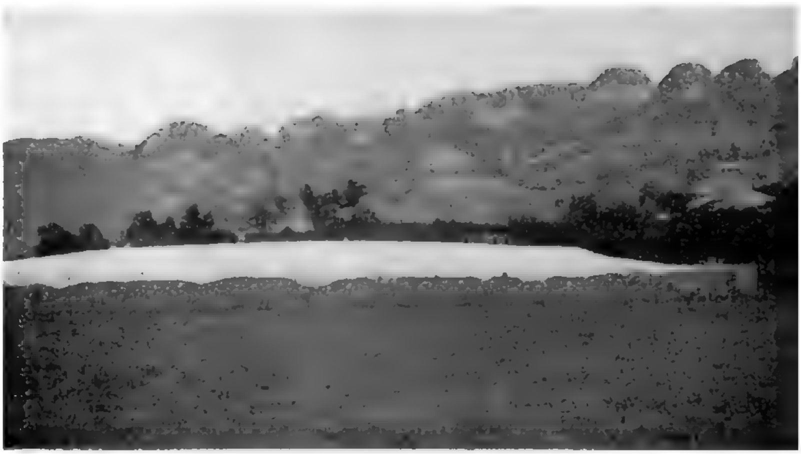

FIGURE 50.—Tobacco seedbed under cheesecloth near Ciales. Limestone escarpment in the distance.

Semillero de tabaco bajo toldo cerca de Ciales. Escarpa caliza a lo lejos.

appearance of a gridiron (fig. 51). These ditches enable the water to drain rapidly without causing serious loss of soil from the fields. The water travels but a short distance before it enters a ditch, and therefore it does not have time to develop much force to carry soil particles. This method seems to be the best of any tried for the prevention of serious erosion on the steep hillsides. Even with the many ditches, there is some erosion, but this must be expected when clean cultivation is practiced on hillsides having 80- to 100-percent slopes. There is only a small amount of gully erosion, however, as the bottoms of the ditches are bedrock.

For a good quality of tobacco, it is of utmost importance to use well-drained soils. Poorly drained soils are referred to by many farmers as "cold" soils for tobacco, and they produce tobacco of poor quality. Many of the sandy-textured soils produce a better quality of leaf than do highly fertile clay or silty clay soils. Salt spray as well as chlorides in the soil affect the quality.

Tobacco requires considerable quantities of readily available nitrogen and potash. The first application of fertilizer generally is made a few days before planting, at the rate of about 400 pounds to the acre of a 6–7–8 formula,[18] and a duplicate application is made about 30

[18] Percentages, respectively, of nitrogen, phosphoric acid, and potash.

days later. The fertilizer requirements for one soil type may or may not be the same as for another, and only by experience and experimentation can the best formula be obtained. The kind and quantity of fertilizer used vary somewhat for the different kinds of tobacco.

Land for tobacco is cultivated two or three times, depending on the weed growth. Generally all cultivation is done by hand, especially on the steep hillsides. Hoeings should be made with the contour of the land or up the slope rather than down the slope, as the latter practice tends to transfer the soil down the slope continually.

About 35 days after transplanting, the lower leaves of the tobacco plant should be removed, in order to increase the circulation of air

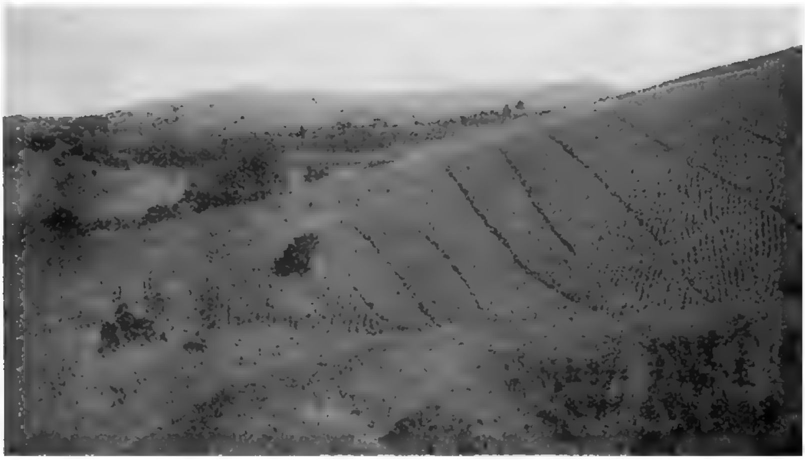

Figure 51.—Tobacco grown on Múcara silty clay loam having a slope ranging from 15 to 60 percent. Note the gridiron drainage ditches. The water travels but a short way before it enters a ditch and therefore does not have time to develop much force for carrying soil particles.

Tabaco cosechado en Múcara limo-arcilloso lómico con un declive que varia de 15 a 60 por ciento. Nótese las zanjas de avenamiento. El agua camina muy poco antes de entrar a una zanja y por lo tanto no tiene tiempo de desarrollar fuerza suficiente para transportar partículas de suelo.

The terminal bud is pinched off at this time or a week or two later, except from plants to be used for seed. The plant should be pruned, leaving from 12 to 16 well-developed healthy leaves. Any suckers that appear after pruning should be pinched off fairly near the axil.

Two methods are used in harvesting, which is done within about 90 days from the time the plants are transferred to the field. One is to cut the entire plant when the leaves are yellowish green or yellowish brown. The cut plants are allowed to wilt in the field, then are carried to the tobacco shed and hung bottom end up to dry on 6-foot sticks or bamboo poles that are suspended horizontally in racks one above the other in six or seven tiers. The drying process is very gradual, and the leaves and stems become yellowish brown and somewhat tough. The other method is to hand-pick the ripe leaves at three different periods, starting first with the bottom leaves, then the middle or best quality leaves, and finally the top ones. When the leaves are being transported to the barn they should be protected

from dust and sunlight. In the drying barns the leaves from the different parts of the stem are kept on separate racks.

The leaves are stored in the drying barn for a period ranging from 20 to 30 days, depending on the weather. The barns or curing sheds are built to protect the leaves from the sun, air currents, and excessive humidity. Many different kinds of barns are in use, but the most common type in the large tobacco-growing section near Cayey is a wooden well-constructed tight-roofed building from 36 to 120 feet long, 15 to 30 feet wide, and 15 to 30 feet high, with ventilation on all sides. The height should equal the width. Many tobacco barns in other districts, some of which are not more than 10 feet high, are thatched with palm leaves and covered with matojo grass. On some of the smaller farms the farmers cure their tobacco in their dwellings (fig. 52) or in open sheds or barns, most of which seem to be located

Figure 52.—Curing tobacco on the side of a dwelling.
Curando tabaco al lado de una casa.

without much regard to prevailing winds or exposure. They should be so placed that they could have, if necessary, a good draft throughout the building and should be located convenient to the tobacco fields.

Owing to a high content of moisture in the tobacco leaves, the drying process must be watched closely, in order that the best chemical changes may take place. The buildings must be closed during cold nights and rainy days, and at times charcoal must be burned, to provide sufficient heat during long wet periods. During clear dry days sufficient ventilation must be made by opening windows or doors.

When the midribs of the leaves are wrinkled and dry, the leaves have dried sufficiently to be removed from their supports in the drying barn and transferred to piles. This operation generally is done in the early morning when the leaves are moist and flexible and are less likely to be injured than if moved during the hot afternoon when they are dry and brittle. The stems, together with the leaves, are put in piles from 3 to 6 feet high, covered with banana leaves, and weighted with

rocks so that the plants will undergo a sweat. The length of time for the first sweat depends on climatic conditions and ranges from 1 to 6 days. The leaves are then stripped from the stem and separated, according to quality, in three grades and tied into bunches known as manillas. These are taken to the fermentation house for fermentation. The fermentation house, which generally is small, should have a wooden floor and very few windows, as air currents should be avoided. The different grades of leaves are placed in separate piles about 5 feet wide, 10 feet long, and 4 feet high, and are covered with sacks.

If the leaves have been removed from the stems in the field and classified when put in the tobacco barn, they are tied into packs when dried and also taken to the fermentation house and put in piles for fermentation. In order to obtain high-quality tobacco, the fermentation process must be watched closely, to see that the leaves in the piles have the proper moisture content and gradually heat to about 132° F., then gradually reduce to 80°, the temperature of the building. Tobacco generally is in fermentation for about 3 months, and during this time the piles may have to be opened, ventilated, and rebuilt many times, in order to keep the leaves from becoming too hot, glued to each other, or deteriorated in quality.

Most of the tobacco grown on the island is for cigar filler, although most of that produced near Isabela is used for chewing. A few years ago considerable cigar-wrapper tobacco was grown under cheesecloth cover, but this is not the present practice. Practically no green-leaved cigarette tobacco is grown, although the sandy-textured soils of the Bayamón and Maleza series and many other coastal plains soils should be adapted for this kind of tobacco if they were properly fertilized and the proper variety of tobacco planted.

The principal variety grown is Virginia Blanca, which can be harvested either by picking the leaf or by cutting the entire plant. It is used for cigar filler. The Gigante is grown to some extent in dry areas. The Connecticut Round Tip at one time was grown extensively under cover.

The principal disease affecting the seedbed is salcocho, or damping-off disease, which is controlled by spraying the soil with bordeaux mixture. The changa is destructive to young tobacco plants, especially in sandy soils. This pest is controlled by putting paris green and wheat flour around the tobacco stems or by encasing the young stems with mamey leaves. Flea beetles and certain worms, such as the gusano, gusano verde, pega pega, leaf miner, cuerudo, agrimensor verde, and tijerillas, are pests in the tobacco districts. Flea beetles are controlled by submerging the tops of the tobacco plants in lead arsenate solution before they are transplanted in the field. All the worms, except the leaf miner, are controlled by dusting the plants with lead arsenate.

Tobacco mosaic, black shank, leaf spot, and bacterial wilt are diseases attacking the plants. Mosaic and black shank are controlled by destroying the infected plants. There is at present no known control for leaf spot. Bacterial wilt is controlled by planting wilt-resistant varieties.

The farms in the tobacco-growing sections are of various sizes. In the Cayey district the average size probably is about 100 acres, about 45 acres of which are in pasture, 30 acres in minor crops, such as corn, beans, sweetpotatoes, and pigeonpeas, ranking in acreage in

the order named, 20 acres in tobacco, and possibly a small acreage in rice and coffee. The tobacco farms in the Isabela district are very small, probably averaging less than 15 acres each, with more than one-half of their area in pasture and almost valueless brush. Of the 7 or 8 acres in cultivated crops, corn probably occupies about 2½ acres, beans 1½ acres, sweetpotatoes 1 acre, and tobacco 1 acre; and the remaining acreage is divided among plantains, pigeonpeas, yuca, ñames, yautia, and other subsistence crops. The average size of the tobacco farms in the Utuado section is about 30 acres. Pasture probably occupies about 10 acres; corn, coffee, and tobacco about equal areas, or about 5 acres each; and the remaining 5 acres is used for the production of subsistence crops, such as sweetpotatoes, beans, yautia, and pigeonpeas. An average tobacco farm in the semiarid section along the southern coast includes about 40 acres. Probably 30 acres are in pasture, 5 in tobacco, and the remaining 5 in corn, beans, and other subsistence crops. At one time considerable cotton was grown on these farms.

It is rather questionable whether the average size of the tobacco farms will increase, that is, farms on which much of the income must be derived from subsistence crops, in order to insure a living. More net income to the acre is made on large tobacco farms than on small ones, but a small acreage of tobacco can be planted by nearly every farmer who plants subsistence crops in the tobacco-growing districts, and he will continue to do so even though the cash returns may be small. Subsistence farms undoubtedly will increase in number and decrease in size as the increasing pressure of the population forces people to cultivate the steeper hillsides.

The acre yield of tobacco is very similar to that in the United States. In the vicinity of Isabela, acre yields ranging from 400 to 600 pounds are common on the nonirrigated areas and from 700 to 900 pounds on the irrigated lands. This tobacco is used for chewing and is twisted in long ropelike pieces. It is sold in rolls of 25 or 30 pounds, at a price ranging from $18 to $24 a hundred pounds. Tobacco does not need nearly so much water as does sugarcane; therefore the farmers who grow tobacco are reluctant in using irrigation water, although it is available and increases the yield considerably, especially during very dry years. The production in the Cayey section ranges from 2,000 pounds to the acre on the good Toa and Estación soils to 400 pounds on the poorer grades of the Múcara soils. Most of the tobacco grown on average Múcara soils yields about 700 pounds an acre. The price for this tobacco is about $25 or $30 a hundred pounds. The yield, price, and quality of the tobacco grown near Utuado are comparable to those of tobacco grown near San Lorenzo, which are nearly as good as of that grown near Cayey. Production is low on the land in the semiarid section along the south coast, and it probably will continue to be low, owing to the frequency of dry years. Most of the land in this locality now used for tobacco would not be very well adapted for tobacco if it were irrigated, but it would be very good for sugarcane.

The general rotation practiced among tobacco growers is to prepare the land for such minor crops as corn, beans, or sweetpotatoes soon after the tobacco crop is harvested (fig. 53). The minor crops derive some benefit from the fertilizer applied for the tobacco and produce

an additional income. After these crops are harvested the land is prepared for the next crop of tobacco. The practice of producing tobacco on the same land year after year applies to the good level alluvial lands and the better grades of hill land. The steeper hillsides generally are planted to tobacco every 2 or 3 years and during the other years are in pasture or minor crops. In the vicinity of San Lorenzo considerable rice is planted after the tobacco has been harvested.

The future outlook for the production of tobacco is fairly good for ambitious, efficient young farmers, assuming that tobacco will continue to be protected by the tariff and that the island will not be forced to sell on the open market. The ever-changing economic conditions may in time be such that only small acreages will be devoted to tobacco in certain districts, but, owing to favorable climate, soils, and a crop which lends itself to small-scale farming, tobacco should continue

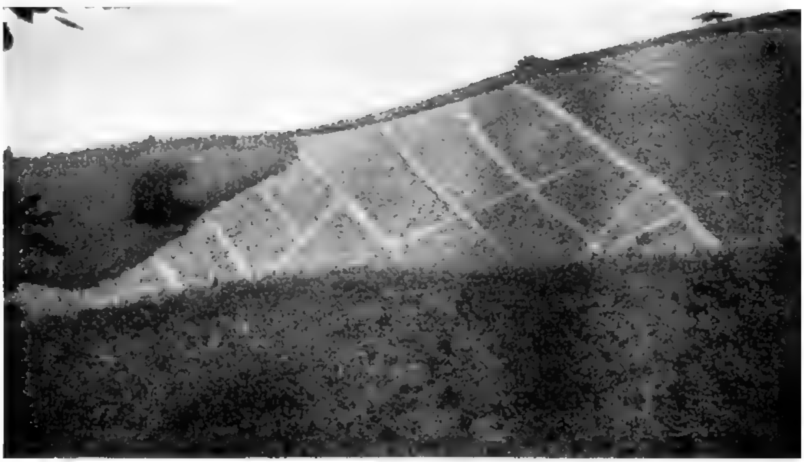

FIGURE 53.—Same area as that in figure 51. Picture taken a few months later. Corn, beans, and yautia are growing on land that was in tobacco a few months before.

La misma área de la fig. 51. Fotografía tomada unos meses más tarde. Siembras de maíz, habichuelas y yautía donde meses antes había tabaco.

to be the second leading commercial crop, and many thousands of laborers should obtain employment in the tobacco-stripping shops. Disputes between employees and employers which terminated in strikes have resulted in a curtailment of the acreage and a loss both to the employees and employers.

The quality of the tobacco should be improved, as the market favors a filler tobacco that has perfect combustibility and an agreeable aroma. The wrapper tobacco should contain a small quantity of nicotine and have a light color, fine texture, and small veins. The chewing, or roll, tobacco should contain considerable glutinous juice and be fairly sweet.

Living conditions could be improved on all the farms producing tobacco if more livestock were produced to supply a milk, cheese, butter, and meat diet to the people who now receive a very low percentage of protein in their food.

COFFEE (CAFÉ)

Coffee is believed to have been introduced into Puerto Rico in the eighteenth century by the French refugees from Haiti. The crop is produced on a low, diffusely branched small tree or shrub that is always green. The coffee tree has a soft gray bark and dark-green glossy

FIGURE 54.—Coffee berries are produced on the 1½- or 2-year-old growth of the lateral branches. (Courtesy of Office of Experiment Stations, U. S. Department of Agriculture.)

La uva del café se produce en las ramas laterales de 1½ ó 2 años de edad. (Cortesía de la Oficina de Estaciones Experimentales.)

oblong leaves. The blossoms are star-shaped, have white petals and yellow centers, and have both fragrance and beauty. The dull-green plump olive-shaped berries grow in clusters close to the stem in the axils of the leaves (fig. 54) and turn red when ripe. Most of them are

produced on the 1½- or 2-year-old growth of the lateral branches, although some are produced on the 3-, 4-, and 5-year-old branches.

At elevations ranging from 1,000 to 1,500 feet above sea level the coffee berries begin to ripen during September and October, or about 7 months from the time of blossoming. At elevations of about 80 feet, such as in the vicinity of Mayagüez, blossoming is advanced at least a month ahead of that at the higher elevations.

Each coffee berry contains two seeds, or coffee beans. The first berries picked are of poor quality. The main crop matures in October or November, depending on the elevation, and it is picked at intervals of about 15 days until all the berries have been gathered. The several ripenings correspond to the several blossomings in the spring. Only the ripe berries are picked, except at the last picking, when all the remaining berries are collected. The pickers, mostly women and children, strip the ripe berries from the branches, allowing them to drop into baskets, and, in turn, they are emptied into sacks which are carried when filled to the drying floor, where the berries are spread to dry overnight. In the morning they are sorted and taken to the hulling machine, or despulpadora, which consists either of one roller with many dull-pointed nails or the more modern disk-shaped machine. The machines may be turned by hand or by power, depending on their size. They remove the outer hull, or pulp, which falls to one side and is later used as a fertilizer. The coffee grains fall into a fairly large bin where they sweat or ferment for a period ranging from 8 to 12 hours. This process loosens the sweet sticky colorless substance called baba with which they are covered. The baba must be removed, and it is more easily washed off after the berries sweat for a few hours. During the washing process the poorer grains float and are strained off. After the water is drained away, the berries are taken to the dryer which usually is either a cement floor, called glacis, or consists of large shallow boxes, called correderas, that are mounted on tracks and can be pushed out in the sun during the day and put under shelter during rains and at night. The coffee is stirred occasionally, so that all the excess wash water will evaporate. When this operation is completed the coffee is said to be enjugado, or in a semidry condition. Every hundred pounds of this semidry coffee will make 46 pounds of cáscara seca, or dry coffee. To obtain the dry coffee, the natural water in the berry must be evaporated. This is done, in most places, by putting the berries in toldas, or square pieces of cloth, and placing them in the sun or directly on the glacis (fig. 29). It takes from 3 to 5 days to dry the berries. A hundred pounds of the dry coffee will make only 80 pounds of coffee ready to be roasted, as the yellow brittle outer covering must yet be removed. This may or may not be done on the farm. The coffee is sacked in 100-pound bags, and generally two bags are strapped to the back of a mule or a pony and thus conveyed to town or to the highway and then loaded into trucks to be taken to town where the coffee is sold or stored for future market. The wholesale dealer generally hulls, sorts, sizes, and polishes the coffee before he sells it. The price of coffee on the farm ranges from $10 to $24 a hundred pounds, depending on the supply, market demand, and quality. Coffee yields range from less than 50 pounds to more than 600 pounds an acre, depending on the soil, location, age and number of trees, condition of shade trees, management, and climate. The variety most commonly grown is *Coffea*

arabica (*29, p. 2*), and for high yields and long production it must be protected from the direct sunlight, although a medium amount of diffused sunlight is essential. Bananas and plantains are planted for temporary shade or until the permanent shade trees supply the coffee trees with enough protection from the sun. The trees commonly planted for permanent shade (fig. 55) are the guamá, on wind-exposed slopes and on high elevations, and the guaba and moca on medium elevations. The guamá is an excellent shade tree, but it is susceptible to injury from the hormigüilla, a small ant that migrates to the coffee trees from heavily infested shade trees. This insect bores tunnels in the coffee trees, thereby weakening the branches, causing them to be easily broken by the wind and during harvest. The guaba tree is preferred to the moca, as it is a fast-growing tree, is easily pruned, and does not scatter hundreds of prolific seeds as does the moca. Cutting the seedlings of the moca increases the cost of cultivation of coffee.

The shade trees should be spaced from 24 to 30 feet apart each way when they are fully grown, but they must be planted much thicker and some trees eliminated as they develop. The coffee trees should be planted about 9 feet apart. The height of the coffee tree should not be much more than 9 feet, in order that the crop may be gathered easily and also that many lateral berry-producing branches will be formed. The height of the coffee trees can be regulated to some extent by the number of shade trees planted to the acre and by pruning.

Coffee can be grown on the same land for many years. The coffee trees are fully grown at about 10 years of age, and they will continue to produce for another 10 years or more if they receive proper care. Each tree varies in yield in accordance with location, fertility, soil, shade, moisture, and vigor. Yields range from less than one-fourth pound to nearly 5 pounds a tree. Under favorable conditions and proper management the trees start producing 18 months after planting, but, as a general rule, very few berries are produced before the third year, and even under favorable conditions most trees do not produce more than one-half pound of berries each before they are 5 years old. The yields of coffee usually are higher every second year, partly because after a heavy production the trees have fed so heavily on the soil nutrients that nearly 2 years are required for the trees to obtain from the soil sufficient available nutrients to produce another good crop. The difference in yearly yields is not so noticeable if fertilizer is used each year. The production of coffee is much higher on concave slopes where the soil is richer and deeper than on the convex slopes. Coffee that will yield 50 pounds to the acre on convex slopes will yield from 300 to 500 pounds on concave slopes. Yields of coffee decrease with an increase in the slope of the land. Fairly high yields can be grown on 60-percent slopes, however, but yields are low on slopes ranging from 80 to 100 percent. Some of the best coffee farms are in Barrios Mameyes Abajo and Tetuán in the municipality of Utuado and in Barrio Frontón in the municipality of Ciales. Most of these farms are on slopes of 30 or 35 percent, and the soil is deep, is well drained, and is high in organic matter. Land values vary with location, road facilities, elevation, soil, degree of slope, extent to which erosion has taken place, and climate. At present (1938) land in good productive coffee trees, yielding about 400 pounds to the acre, is valued between $125 and $150 an acre. Land producing about 200 pounds

is valued at $80 or $90, and land producing only 50 pounds is valued at $40 or $50. Similar land in pasture is valued at about $30 or $40. The estimated cost of planting an acre of coffee trees is about $50.

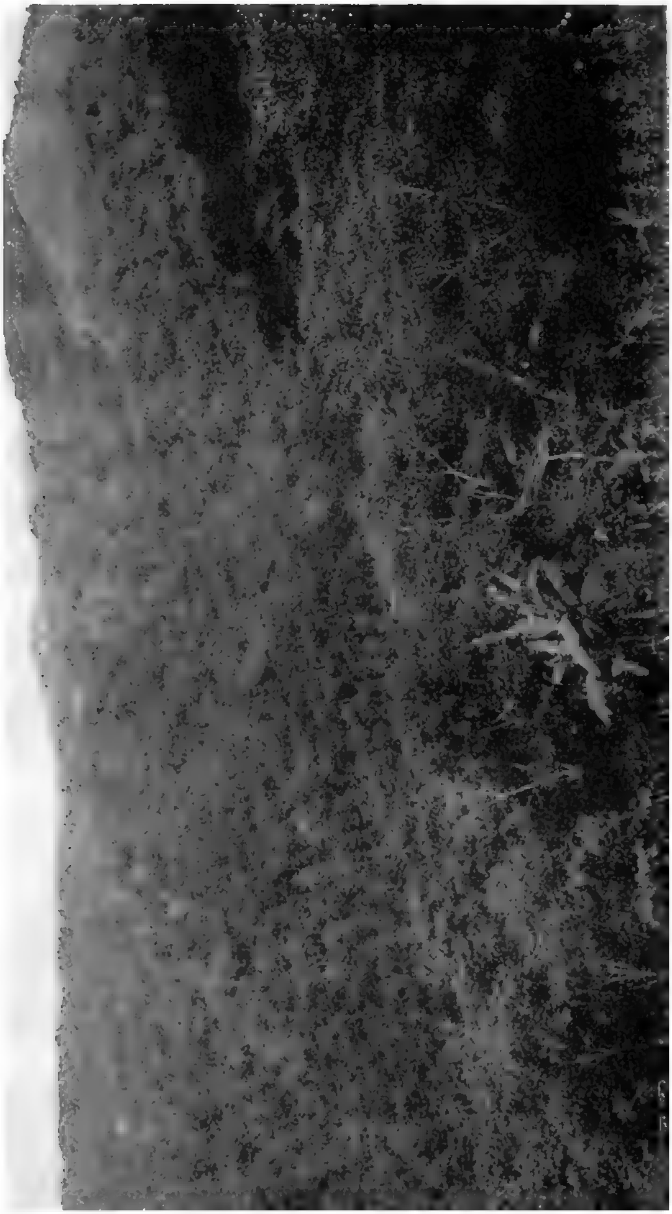

FIGURE 55.—A coffee finca near Ciales. The shade trees are too close together and therefore form too dense a shade. Corn and some bananas in the foreground.

Finca de café cerca de Ciales. Los árboles de sombra están demasiado juntos y por lo tanto dan demasiada sombra. Maíz y guineos al frente.

Coffee of the best quality is grown at elevations of more than 1,500 feet above sea level, but, owing to the greater destruction from wind at high elevations, most of the coffee now grown is below an elevation

of 1,500 feet. At one time large areas of land above 1,500 feet were in coffee. At present the proportion of coffee grown at elevations above 1,500 feet is larger on the south side of the Cordillera Central than on the north side. This is especially true in the area north and west of Villalba. The coffee farms are of various sizes. A few include a thousand acres, many range from 10 to 20 acres, but most of them are between 100 and 200 acres. A 40-acre farm is about as large as can be handled efficiently by one man. The number of laborers required for an average 140- or 150-acre farm is about 20. The men are paid about 50 cents a day. Coffee pickers are paid from 5 to 7 cents an almud [19] which is about 5 gallons, or 20 liters. An average picker can gather from 4 to 6 almuds a day. Most of the pickers are women and children.

Usually each peon helper has the privilege of planting an acre or more to subsistence crops for his own use. He generally gathers all the bananas he can eat from his employer's land, and many employers permit the gathering of wood to be made into charcoal. It is customary for the peon helper to build his own house, or bohío, on his employer's coffee finca. The bohíos commonly are very crudely constructed one- or two-room structures with a lean-to for cooking. Only the bare necessities are in these bohíos. Most of the owners of coffee farms have a four-room house and several other buildings, such as sheds and places to wash and dry the coffee. Most of them do not attempt to produce other commercial crops, but they do gather and sell the sweet juicy mountain oranges that grow abundantly on their land. Owing to the excellent quality of these oranges, nearly all are sold on the local markets. The price is low, averaging from 25 cents a hundred during the fall and winter to $2 a hundred during the spring and early summer.

Coffee farmers have had many set-backs, owing mostly to destructive hurricanes, such as those in 1898, 1928, and 1932. Most of the farms are heavily mortgaged. Seven years after the hurricane of 1928, the value (*16, p. 120*) of the coffee exported from the island was $207,739, or only 3.4 percent of the value of that exported in 1919, an average year from 1911 to 1927. The coffee farms were so severely damaged by the 1928 hurricane that only a small proportion of the farmers began immediately after the storm to replant their coffee and shade trees. Many of those who did replant utilized only the most favorably located and least damaged parts of their farms and allowed the rest to grow up to brush and grass. Now nearly 60 percent of the total coffee area is either in grass, brush, or poor-quality trees. The proportion of idle and forested land is greater than land in coffee at elevations above 2,000 feet, but a higher proportion of the land is in coffee than is idle at elevations below 1,500 feet. This is because the winds were more destructive at the higher elevations. The proportion of idle land on the north and east slopes is greater than on the south and west slopes, because there is less protection from the winds on the windward sides of the hills and mountains. This can be seen readily in studying Puerto Rico's agriculture from an airplane. The most ideal location for a coffee farm is on the southwest slope of a half-cup shaped, gently sloping mountainside, at an elevation ranging from 1,500 to 1,700 feet, where the average annual rainfall is more than 84 inches and where the soil is not greatly eroded but is friable,

[19] 1 almud of coffee berries makes about 5 pounds of marketable coffee.

well-drained, deep, and contains about 3 or 4 percent of organic matter in the upper 8 inches. Coffee roots penetrate deeply. They are highly susceptible to stagnant ground water and cannot tolerate many floodings. Some of the necessary coffee roots develop only in the presence of humus, therefore the soil must be fertile. The water requirements for coffee are about the same as for cacao trees, slightly less than for sugar beets, but much more than for cotton, coconut palms, and corn.

Figure 56 shows the distribution of coffee trees in Puerto Rico as recorded by the Puerto Rico Reconstruction Administration special census for 1935. It may readily be seen that nearly all the coffee is grown in cool temperatures, at high elevations, and in localities where the average annual rainfall is greater than 80 inches. Exceptions occur, as a few small areas are in coffee southwest of Isabela, where the average annual rainfall is not more than 58 inches, and near San Germán, where it is 65 or 70 inches. Coffee grown in areas having less than 80 inches of annual precipitation produces low yields, and the leaves are attacked by the coffee leaf miner. According to the Puerto Rico Reconstruction Administration census of 1935, more than one-half of the total number of coffee trees growing on the island are in the municipalities of Utuado, Lares, Maricao, Las Marías, Adjuntas, Mayagüez, Ciales, and Jayuya. From 50 to 80 percent of the total farm land of these municipalities is planted to coffee. About one-fourth of the total farm land of the island was in coffee in 1935.

One reason that such a high percentage of coffee is grown in the municipalities mentioned is the scarcity of good roads. The only means of transportation from some of the farms is by mule or horse over narrow steep trails, and by such transportation it is easier and cheaper to transport coffee than most of the other crops grown. Also, coffee is not perishable and can withstand rather rough handling, which is a factor to be considered when transportation is made with pack animals.

The distribution of coffee trees coincides very closely with the distribution of the soils of four extensive upland soil series, namely: Catalina, Alonso, Los Guineos, and Cialitos. These are acid friable deep or fairly deep well-drained red or purple permeable clay soils, and they receive an average annual rainfall in excess of 78 inches. All are adapted to the production of coffee. The Alonso soils are considered the best, followed in order by the Catalina, Cialitos, and Los Guineos. In some places along the north coast, coffee is grown at elevations of less than 500 feet, on such land as Tanamá stony clay, colluvial phase, Tanamá stony clay, and associated soils derived from limestone. These soils are not considered good soils for coffee, and a high yield is very unusual. Coffee is grown on such land because the soil is of little value for other crops, partly because of its inaccessibility. The Lares, Torres, Toa, and the best Múcara soils are well adapted to the production of coffee, but, as sugarcane is a more profitable crop, only a small area is planted to coffee. Most of the Toa soils in the coffee districts are used appropriately for the coffee seedbeds.

Coffee trees should be planted at the rate of about 600 to the acre or from 8 to 10 feet apart, but on most of the coffee farms the trees are planted promiscuously over the farm, from 900 to 1,400 an acre, and often three or four seedlings in one place. The coffee seedlings should

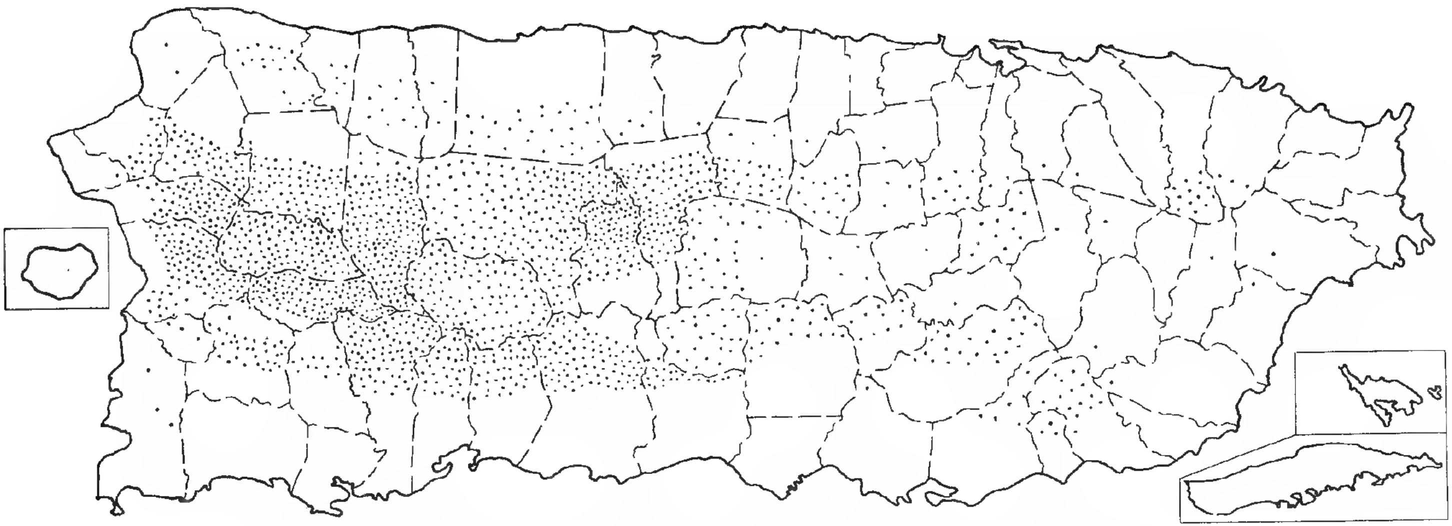

FIGURE 56.—Distribution of coffee trees in 1935. Each dot represents 100 acres.
Distribución de árboles de café en 1935. Cada punto representa 100 acres.

be transplanted from the nursery to the field at the age of approximately 1½ years, and the best time for planting them is just before the rainy season. The general practice is to plant the seedlings in holes about 18 inches square, and, on slopes, the plantings should follow the contours. For best production, coffee trees require diffused sunlight and good low-air circulation. It is best not to cultivate coffee land, especially that on slopes. At the beginning of the dry season, the grass and weeds near the coffee trees should be cut and all leaves and trash allowed to decay on the land. One of the most necessary procedures in handling hill-land coffee farms is to keep the surface soil from becoming low in plant nutrients or from being washed away by sheet erosion. This is best prevented by fertilization and by encouraging grass and cohitre morado to grow. Grass will not grow luxuriantly because most of the ground is shaded, but cohitre morado will grow very well, even on rocks, and it is a good plant for helping in the prevention of erosion. The coffee trees, as well as the shade trees, protect the land from erosion. Most land that has been in coffee for many years and properly managed has a 6-inch surface soil, but in much of the adjacent cultivated land the surface soil is only 2 inches thick, and in many places the subsoil is exposed.

Many farmers find it good policy to dig holes about a foot square and from 8 to 14 inches deep near most of the coffee trees, in order to prevent erosion. Digging the holes costs about $5 an acre. The holes are partly filled with manure or leaves to keep the tree roots from exposure, to add fertility to the soil, and to keep the soil moist. During rains, these holes serve to catch the flowing water and sediments and also to check the force of the water. The holes fill with soil within a period ranging from 2 to 4 years. Some farmers clean them and scatter their contents around the trees and others dig new holes, and the process is repeated.

Another good soil-conservation practice is to dig deep long pits along drainageways and hillside roads. The running water fills one hole after the other, but the force of the water is checked and some of the sediment has time to settle in each hole. In time these holes fill with sediments, after which their contents are scattered over the hillside from which they were washed.

The coffee trees should be fertilized at the rate of about 1 or 1½ pounds of mixed fertilizer, such as a 10–5–15 mixture, or about 5 pounds of manure, to the tree. The Federal experiment station at Mayagüez has had good results with a 7–10½–14 mixture. Some farmers use 100 pounds of ammonium sulfate and 200 pounds of potassium sulfate to the acre. A very small proportion of the farmers fertilize their coffee trees, but when fertilizer is used, it is generally applied in November and again in May or June. The production of coffee has varied greatly from year to year. In 1770, 728,025 pounds (*16, p. 796*) was produced. The market at that time was limited to Mediterranean ports. The production nearly doubled in the next 6 years, on account of the remission of taxes. Coffee did not hold an important place in the agriculture of the island until nearly 100 years later, when the United States took possession, at which time coffee was the most important crop, outranking sugarcane and all other crops by a wide margin. The hurricane of 1898, however, was so destructive to the coffee trees, and the impetus given the production of sugarcane by free trade was so great, that within a

very short time sugarcane was the leading crop. In 1850 the production of coffee amounted to 11,783,684 pounds, in 1870 to 17,416,762 pounds, and in 1897 to 51,710,997 pounds (*16, p. 796*). According to the Puerto Rico Reconstruction Administration census, the production was 53,209,362 pounds in 1919, only 7,331,877 pounds in 1929, owing to the severe hurricane in 1928, and 25,855,543 pounds in 1935. In the latter year the area in coffee represented 25.6 percent of the land from which crops were harvested.

In 1939 most of the coffee was exported to Czechoslovakia, Sweden, France, and the Netherlands, and some went to Switzerland and Italy. The value of export coffee ranged from $1,678,765 in 1901 to $9,034,028 in 1920 (*16, p. 120*). According to the 1938–39 Annual Book on Statistics, the value dropped to a low of $124,558 in 1933, reached a high of $1,169,684 in 1937, and fell again to $527,101 in 1939.

The future of the coffee industry is anything but encouraging. The exportation of coffee for the last 20 years has declined gradually, and during the last 6 years exportation has been so low that Puerto Rico has lost much of her European trade for this commodity. A very small quantity of Puerto Rican coffee is sent to the United States, and, therefore, nearly the entire exported crop enters the world market on a competitive basis. The coffee produced is of a mild excellent quality, but, because of the low acre yield, the growers must realize a very high price in order to make a profit.

In many areas within a kilometer of the main highways, sugarcane gradually is crowding out coffee. In some areas in the east-central part of the island, tobacco has been planted on the Múcara and associated brown shallow soils that once were fairly productive land for coffee but now, after a period ranging from 10 to 15 years of clean cultivation to tobacco and minor crops, these soils are so shallow that if coffee were planted, the crop would be a failure or very low yields would be produced. So far no crop has been grown on the island that will compete with well-cared-for coffee planted on the deep red acid Catalina and associated steep soils of the upland, which are in the high-rainfall areas. But even with good land, the successful coffee farmers will be those who take care of their own land, working it with their own families, and those who plant other crops adaptable to the soil, such as mountain oranges, plantains, bananas, vanilla, ñames, and yautia, and in addition have some livestock for consuming the grass grown on the land not suitable for coffee. Growers should have their own seedbeds, and immediately after a hurricane they should rebuild their farms. They will have to use more and more fertilizer, manure, and lime, as the years go by. In order to compete with other coffee-producing countries, which produce much higher acre yields, have less loss from hurricanes, and have cheaper land and labor, the farms must be well managed, the noxious weeds and vines must be cut, and the shade trees must be kept in good condition, in order that the losses from ants and diseases may be kept to a minimum. The coffee trees should be pruned systematically, and a continuous effort must be made to keep soil erosion at a minimum.

GRAPEFRUIT (TORONJA)

Puerto Rico had very few, if any, commercial grapefruit orchards before American occupation in 1898, but long before that date grapefruit was growing wild over the island. It is probable that the seeds were brought from land adjacent to the Mediterranean Sea.

The industry grew rapidly between 1900 and 1930, but since 1930 very few commercial orchards have been planted. According to the United States Customs Bureau, San Juan, P. R., $162,749 worth of grapefruit was shipped during the fiscal year 1910. In 1920 nearly 10 times that amount, or $1,332,742 worth, was shipped. According to the Annual Book on Statistics, $315,580 worth of fresh grapefruit and $591,136 worth of canned or preserved grapefruit, or less than 1 percent of the value of all exports, was shipped in 1937. These figures fell to $56,690 and $170,486 respectively in 1939. Most of the shipments are sent to New York City, but small quantities are sold in European markets, chiefly in England.

Most of the grapefruit orchards are owned and managed by continental Americans. The orchards range in size from a few acres to several hundred, but the average size of the commercial orchards is about 125 acres. Figure 57 shows the distribution of grapefruit trees, as recorded from data of the Puerto Rico Reconstruction Administration census of 1935. At that time there were 646,802 bearing trees and 153,120 nonbearing trees. The municipality of Bayamón had 150,207 trees, or about one-fifth of the total number on the island. Other municipalities ranking in number of trees in the order named are: Toa Baja, Manatí, Arecibo, Vega Baja, and Toa Alta. In these six municipalities are about 75 percent of the total number of grapefruit trees in Puerto Rico. From figure 57 it may readily be seen that over 90 percent of the trees are grown in the area between Arecibo and Trujillo Alto. Most of the soils in this area are derived from limestone, no part has an annual rainfall of less than 65 inches, and most of the area lies at an elevation of less than 300 feet, especially the land in grapefruit. Almost all the commercial orchards on the island are at elevations of less than 500 feet. Grapefruit growing in areas having an annual rainfall of less than 65 inches should be irrigated. Some growers irrigate in places where the average annual rainfall ranges from 70 to 75 inches.

The most common varieties grown in the commercial orchards are the Duncan or a variety resembling Duncan, the nearly seedless Marsh variety, and Triumph. Most of the growers have small nurseries, and the common practice is to bud grapefruit to grapefruit, or to rough lemon rootstock. Grapefruit trees under favorable conditions should start blooming at the age of 5 years and continue to bear until they are more than 35 or 40 years old. Maximum production is reached when the trees are from 9 to 12 years of age. As it takes more than 7 months for the crop to mature, the blossoms should appear in January, in order that the ripe fruit may reach favorable markets in August and September. At this time the price in New York is about $3 a box. During March it is often less than $2 a box. Locally grapefruit can be bought for $1 a hundred during March, April, May, and June, and $3 a hundred during August, September, October, and November. At times the price paid at the local canneries ranges from $4 to $12 a ton, which is from 20 to 60 cents a box. The season

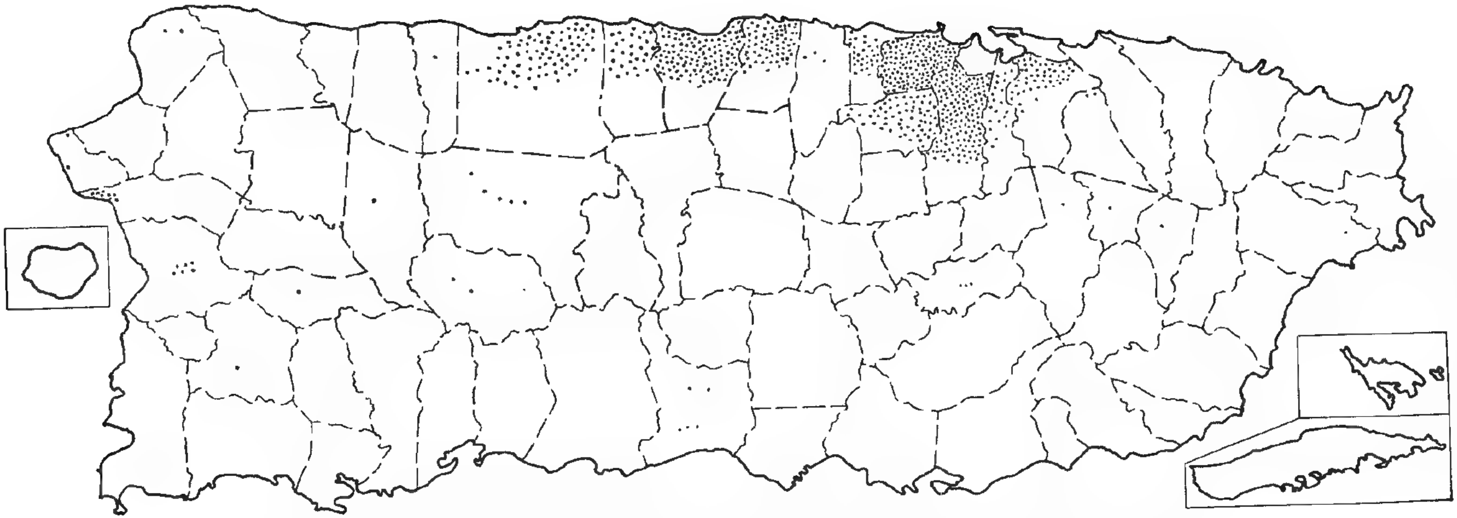

FIGURE 57.—Distribution of grapefruit trees in 1935. Each dot represents 1,000 trees.
Distribución de árboles de toronja en 1935. Cada punto representa 1,000 árboles.

for harvesting is between February and July. Some blossoms may appear between January and April, and it is not uncommon to see fresh blooms, small fruit 1 inch in diameter, and mature fruit on the same tree. A mature tree growing under favorable conditions may reach a height of 15 feet, have a radial branch spread from 12 to 15 feet, and have some roots that penetrate to a depth ranging from 10 to 12 feet.

The size, vigor, and production of the grapefruit trees depend on soil, climate, location, fertilizer, management, variety of tree, disease, and rootstock used for budding.

Grapefruit trees will grow on many soil types, but for a profitable crop during adverse times the land must either be nearly ideal for citrus or so fortunately situated that there will be little or no loss from hurricanes. For highest yields and longest periods of production, grapefruit trees require wind-protected areas in deep well-drained, well-aerated neutral or acid sandy-textured soils, such as the loamy sand and sandy loam types of the Maleza, Coto, Espinosa, Bayamón, Islote, and Vega Alta series, and the calcareous sand and loamy sand types of the well-drained Cataño series. The friable permeable clay soil of the best grades of the rolling to undulating areas of the Catalina and Alonso soils also are well adapted for grapefruit. The roots of the grapefruit trees can rapidly and easily spread and deeply penetrate all these soils, and, with sufficient water and fertilizer, rapid-growing trees are produced. It is unfortunate for the owners that many orchards have been planted on less favorable soils than those mentioned, such as the heavy plastic sticky clay soils of the Moca, Mabí, and Santa Clara series, in all of which internal drainage is too poor for the movement of both air and water, thereby causing the trees to be small and unhealthy; and soils like the Sabana Seca and the heavy-subsoil phases of the Vega Alta, in which the subsoils are too heavy and stiff for the roots to penetrate readily, thereby causing the trees to be stunted after they are 4 or 5 years old. Trees planted on the Corozo, Algarrobo, and St. Lucie soils are small, short, and produce low yields, as these soils are too infertile and too acid for grapefruit, and they also have an impervious layer at a depth ranging from 20 to 48 inches. Neither are the clay soils of the Bayamón, Coto, Vega Alta, Espinosa, and Almirante series very good soils for grapefruit, as they have too heavy surface soils and subsoils for the roots of the trees tc penetrate as freely as they should to procure nutrients to form a large highly productive tree. Of the above-named soils, the lighter the texture the better the soil for grapefruit.

If the trees are planted about 30 feet apart, on a farm having Bayamón clay, Bayamón fine sandy loam, and Bayamón loamy fine sand, closely associated (as is very common), in about 15 or 20 years those on the loamy fine sand may be expected to be nearly three times as large as those on the clay, and the largest trees on the fine sandy loam will be about the size of the smallest trees on the loamy fine sand. The trees on the loamy fine sand will have nearly touched one another, shading nearly all the ground beneath, whereas only about one-half of the ground under the trees on the clay soil will be shaded, and other trees will have to be planted in order to have the total area shaded, thereby keeping down the cost of cutting the grass or the cost of cultivation. This difference in the growth of trees is not so apparent if the land is irrigated or if the average annual rainfall is above 80 Inches.

Production varies greatly according to the soil type. In one well-managed orchard a tree growing on Piñones clay was producing about 2 boxes of grapefruit a year, and not more than 100 feet distant on Bayamón loamy fine sand the production was 20 boxes to the tree, in fact one tree yielded 30 boxes.

The most prosperous looking orchards are those planted on sandy soils and favorably situated in relation to the wind. If the orchard is to be located on wind-exposed areas, good protection from the wind must be established before the trees are planted. The Australian pine is used extensively for this purpose, as it grows rapidly on almost any soil. A growth of 15 or 20 feet a year is not uncommon. In many places these trees are planted in hedges. Another permanent windbreak is the bamboo, which is desirable if a ditch is dug about 30 inches deep between the bamboos and the first row of grapefruit trees, as the roots of the bamboos are heavy water feeders and compete seriously with the grapefruit roots if they become intermingled. In many orchards leguminous crops are planted as protection from the wind, as well as for the fertility they add to the soil. The most common plants of this kind are crotalaria, pigeonpeas, and gallito (*25*). Some of the small circular valleys in the limestone hills are nearly as ideally protected from wind as is possible in Puerto Rico. Many of the limestone hills tower more than 100 feet above the level of the valley floor. Air circulation, however, in general is not so good as in more open and undulating land. Grapefruit trees grow better and are more healthy on slightly undulating land than on flat land or depressions, because of the better drainage and freer circulation of air. The trees cannot endure long if the land is under water for any length of time. Grapefruit trees planted on 30-percent slopes will grow if the soil is suitable, but it is noticed that the trees planted on the concave slopes are much superior to those on the tops of the hills or on the convex slopes. This is due to deeper richer soils and more moisture on the concave slopes, also to better protection from the wind, especially on the south and west slopes.

Good young productive orchards growing on loamy sand in well-protected locations having an average annual rainfall exceeding 75 inches or an economical irrigation system and good circulation of air are valued at $400 or $450 an acre. The same land in sugarcane would be worth not more than $60 or $75 an acre. The value of productive trees ranges from $5 to $9 each.

Grapefruit trees should be planted about 30 feet apart, or about 42 to the acre, in the loamy sands of the following soil series: Maleza, Coto, Bayamón, Espinosa, Cataño, and Vega Alta, and about 27 feet apart in Alonso and Catalina clay. They should be planted about 25 feet apart, or 70 trees to the acre, in sandy loams and loams of the first-mentioned soil series and about 20 feet apart if planted in the sandy clay and clay members of the same series. Each tree should be planted on an 18-inch mound of loose surface soil, in order to protect the tree from root rot. The newly planted trees should be kept watered, to enable the roots to become well established. In the irrigated districts near Isabela, in very permeable soil, a small basin about 6 feet in diameter is dug around each young tree and nearly filled with water. Small laterals spread the irrigation water over the land to the bearing trees. More of the owners of grapefruit orchards are installing irrigation pumps than formerly, especially near the coast

between Bayamón and Arecibo. Through the use of irrigation, the time of blossoming can be controlled better and the yield increased. Other things being equal, the sandier the soil texture the more frequent should be the irrigation and application of fertilizers, but the total quantity applied need not be greater than that for the heavy-textured soils.

Field observations indicate that it is not essential that the soil in grapefruit orchards be cultivated after the trees are more than 4 or 5 years old. After the trees are 5 years old, the grass and weeds should be cut at intervals and kept short during the dry season, but it is not necessary to hoe the land. This saves expense, the grass helps to stop sheet erosion, and the decaying grass roots and leaves are beneficial in enriching the soil. After the trees are large, their shade will kill almost all the undercover.

Fertilizer generally is placed around the tree within the spread of the branches. The formula most commonly used is 6–8–10. From 30 to 35 pounds are used for a tree producing 20 boxes of fruit, and from 15 to 20 pounds for a tree producing 10 boxes or less. The custom is to apply the fertilizer about December 1, again in February, and the third application in June. Young trees require much nitrogen for the formation of roots, trunk, and limbs; but the bearing trees require less nitrogen and more phosphoric acid and potash for the best quality of fruit.

The future of the industry is not encouraging, owing to the frequency of destructive hurricanes, uncertainty of favorable prices, and low yields from orchards unfortunately located on poor soils. Many orchards on the poorer soils are neglected, the grass and weeds are uncut, and no attempt is being made to check the ravages of diseases and insects. Ultimately this land will be planted to more productive crops, probably sugarcane or pineapples. The soils well adapted to grapefruit are producing as high or higher returns from grapefruit than they would produce from any other crop commonly grown. On such soils the yield is high and the quality of the fruit is good. The soil is easily handled and is becoming more fertile with use, owing to frequent applications of fertilizer and the use of adequate methods for the control of erosion.

Some of the growers of citrus fruit claim that grapefruit should be produced at a cost of about 25 or 35 cents a box and that the production should be from 10 to 15 boxes a tree for adequate profit. The average production of a bearing tree is probably about 5 boxes.

Very few acres have been planted to grapefruit trees during the last few years, and it is doubtful whether the acreage will increase within the next few years. There are several undeveloped areas on the island that would make very good land for grapefruit. One is a large area of Maleza loamy sand near Faro Cabo Rojo in the southwestern part of the island. This land should be irrigated. At present it is in guinea grass and corn. An area of Cataño sand and Cataño loamy sand is east of Loíza near the coast. This area also should have some irrigation if grapefruit is to be planted. It is now in minor crops, and some coconut palms are growing on it. Other good soils for grapefruit are the rarely overflowed areas along the north coast and the sandy-textured San Antón soils on the south coast. It is doubtful, however, whether grapefruit will ever compete with sugarcane on the high-priced valuable lands.

PINEAPPLES (PIÑAS)

According to Barrett (*6, p. 246*) the pineapple was almost certainly a native of Brazil, and very probably the Caribs or Arawaks took some to Puerto Rico before the sixteenth century. The Spaniards cultivated this crop to a small extent, and when the island was ceded to the United States the giant Cabezona variety had been developed and was grown in the vicinity of Lajas on the steep hillsides of the Mariana soils. Since that time other varieties, such as the Pan de Azúcar, or sugarloaf, Caraqueña, and Negrita have been grown to some extent in different parts of the island and have been used for home consumption. The principal commercial variety is the Red Spanish which is grown extensively on the soils of the coastal plain from Carolina to Arecibo.

The pineapple is related to the bromeliads and air plants, and it can absorb nutrient constituents through its leaf axils and long-barbed and barbless bayonetlike leaves that protrude from numerous whorls on the main stalk. It apparently is a stemless plant, as the leaves are produced at the surface of the ground. The height of the plant ranges from 2 feet in poor soil to 6 feet in very good soil. The fruit may weigh from 1 to 35 pounds, depending on the variety, soil, climate, and kind and quality of fertilizer used, but the average size of the commercial product is between 2 and 3 pounds. The fruit is produced near the center of the plant on a short bright-red stalk. The so-called fruit is an aggregate of many individual fruits with their fibrous juicy pulp surrounding the core. In some varieties each individual fruit has a number of seeds which can be used for propagation, but the most common practice is to plant slips or suckers. The slip resembles a miniature plant and is produced near the base of the fruit. A small crown slip is produced near the top of the fruit, and although this slip will grow when planted, it is rarely used for propagation. The suckers resemble the slips, but most of them are larger and are produced in the leaf axils. After one crop of pineapples is harvested, a second crop, or ratoon, is produced from a new plant resembling a sucker which is formed at the base of the main stalk in contact with the soil.

The pineapple is a very sensitive plant that responds to good management and good soil, but if the soil is too alkaline, too wet, too compact, or poorly aerated, the crop is very likely to be a complete failure. The pineapple plant is neither deep-rooted nor does it require large quantities of water. It grows best on acid well-drained permeable soils that contain considerable organic matter and are in positions where air drainage is good. The permeable clay soils, such as Catalina clay, Bayamón clay, and Espinosa clay, are slightly more productive than Bayamón sandy clay loam and Espinosa sandy clay. Mariana clay loam, Aguadilla sandy loam, and Sabana Seca sandy clay loam produce fairly good yields. Sabana Seca clay is slightly too heavy and compact for good aeration. The Cataño, Múcara, Colinas, and related soils are too alkaline. The Vega Baja and most of the alluvial soils are too wet.

The acreage in pineapples is relatively low compared to that in other crops, but the total value of the export crop is high. The 1935 Puerto Rico Reconstruction Administration census reports 14,872,929

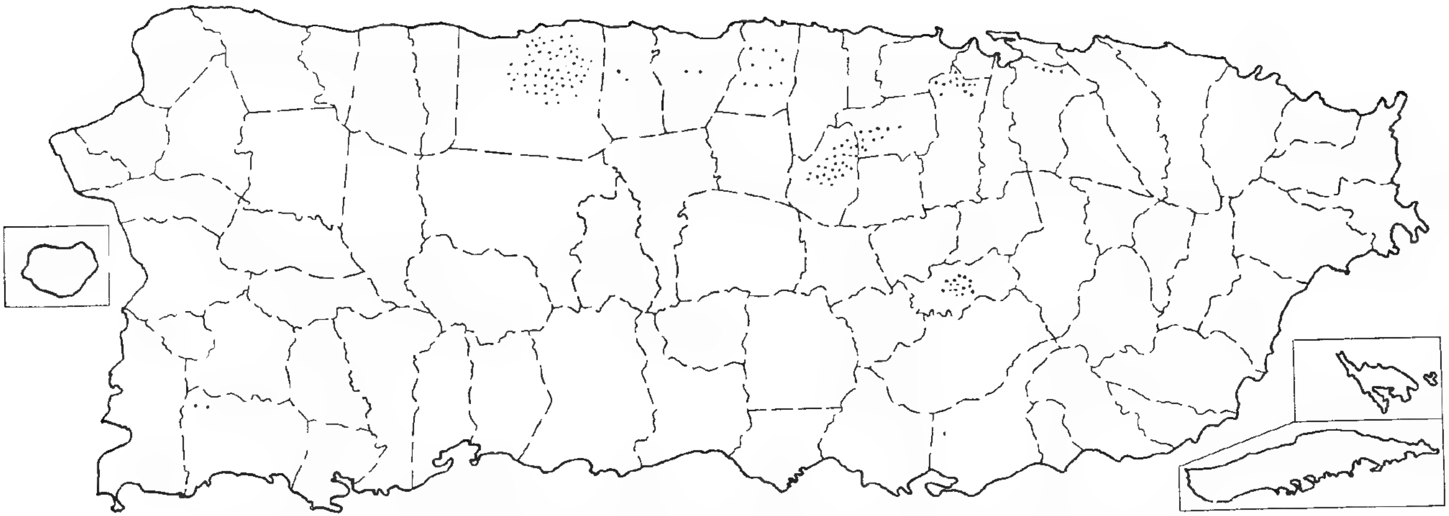

FIGURE 58.—Distribution of pineapple plants in 1935. Each dot represents 100,000 plants.
Distribución de plantas de piña en 1935. Cada punto representa 100,000 plantas.

plants on the island, of which 12,295,777 are bearing. On the assumption of 10,000 plants to the cuerda, only 1,487 cuerdas are planted to pineapples. From field observations this seems too small a figure. Figure 58 shows the distribution of pineapples according to the 1935 Puerto Rico Reconstruction Administration census. About 90 percent of the 14,872,929 plants grow in the municipalities of Arecibo, Corozal, Bayamón, Cidra, Vega Baja, and Toa Baja. Nearly all of the pineapples in the municipalities of Corozal and Cidra are produced on the Catalina, Cialitos, and Lares soils. Most of the pineapples in the municipality of Río Piedras are produced on Sabana Seca sandy clay loam. In the other municipalities mentioned, most of the plants are grown on soils of the Bayamón, Espinosa, and Vega Alta series. According to the 1935–36 Annual Book on Statistics,[20] the value of ex

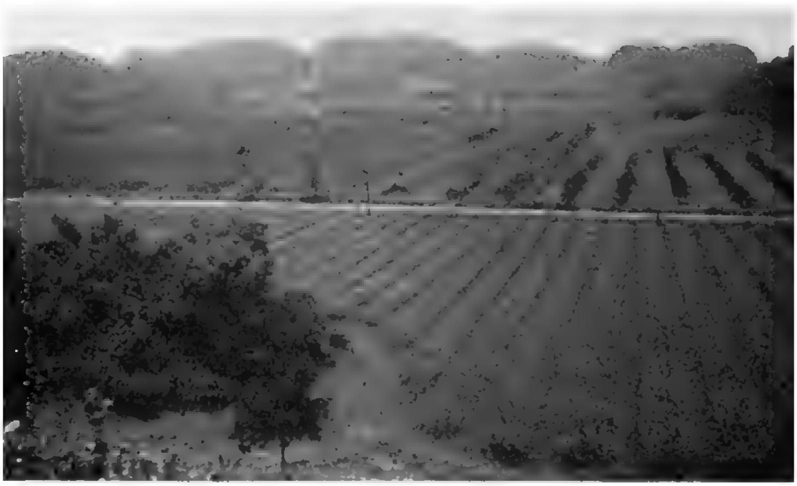

FIGURE 59.—Pineapples growing on Bayamón clay. Four rows are planted to a bed, and the plants are set about 18 inches apart each way. Grapefruit trees on the other side of the road. Tanamá stony clay in the distance.

Piñas sembradas en Bayamón arcilloso. Cuatro hileras forman un banco, y las plantas están sembradas a 18 pulgadas entre sí. Al otro lado de la carretera, árboles de toronja. A lo lejos Tanamá pedrego-arcilloso.

ported pineapples before 1907 was less than $100,000 a year. Exportation gradually increased to $1,723,863 worth in 1915, gradually decreased to $479,461 worth in 1919, reached another peak of $2,278,449 worth in 1931, and again fell off. In 1939 the 463,860 crates exported were valued at $1.66 a crate, or a total of $862,423. Practically all of the pineapples exported were fresh, and nearly all of them were shipped to the United States. Puerto Rican pineapples are of good quality and bring a better price on the New York market than do those from Cuba.

A common procedure of planting pineapples in the nearly level Bayamón, Espinosa, or similar soils (fig. 59) is to have the soil in good tilth by plowing and harrowing at least once, if not twice, and then to plant either slips or suckers during the rainy season, between June and August. Some growers plant 60 percent of their land with suckers

[20] Annual Book on Statististics (1935–36), Government of Puerto Rico, Department of Agriculture and Commerce, Division of Commerce. [Mimeographed.]

FIGURE 60.—Pineapples growing on Catalina clay near Corozal. Crisscross ditches are dug to facilitate the drainage of surplus water from the fields as quickly as possible. Owing to the permeability of the soils and lack of sand grains, there is very little gully erosion in the ditches.

Piñas en Catalina arcilloso cerca de Corozal. Zanjas de cruceta hechas para facilitar el avenamiento rápido del agua. Debido a la permeabilidad de los suelos y escasez de granos de arena, existe muy poca erosión barrancosa en las zanjas.

and 40 percent with slips. The slips generally make a larger plant, but the suckers are easier to plant, as they can be inserted in the ground at almost any depth, whereas the slips must not be set deeper than 2 inches. Both slips and suckers are planted 18 inches apart each way in four rows to a bed. The more permeable the soil, the shallower the bed. It requires about 10,000 slips to plant an acre. The slips or suckers should be vigorous, healthy, and mature. After they are pulled from the mother plant they can be placed in piles for several days before planting and still maintain their vitality.

On the Catalina, Mariana, and similar soils of the uplands three rows of slips or suckers are planted in beds about 6 inches high and 9 feet from center to center. Plants of the large Cabezona variety are set about 2 feet apart, but those of the Red Spanish variety are set the same distance apart as in the Bayamón and other coastal-plain soils. On the hillsides, numerous crisscross ditches (fig. 60) are dug to facilitate drainage of surplus water from the fields as quickly as possible yet maintain a minimum of water erosion. The water flowing across the field enters a ditch before it has time to develop sufficient speed and force to carry large soil particles. Owing to the lack of numerous sand grains and to the permeability of the soils, there is very little gully erosion in the ditches, although some of the ditches extend from the top to the bottom of the hill on slopes ranging from 45 to 70 percent. In the Mariana soils the bottoms of the ditches are bedrock, thus reducing any chance of serious erosion. In many fields it is possible to improve the prevailing planting practices by planting the pineapples with the contour of the land, rather than with the slope, and in many places it would be advantageous if some of the ditches were dug along the contour of the land, if there is no danger of the water overflowing the ditch banks and causing damage.

FIGURE 61.—A gully 2 or 3 feet deep made in Moca loam within 3 months' time. Grapefruit and pineapples planted in the same field.

Zanjón de 2 ó 3 pies de profundidad hecho en el término de 3 meses en Moca lómico. Toronjas y piñas sembradas en el mismo campo.

The steep slopes of the Moca and Lares soils planted to pineapples are very likely to become rather seriously eroded within a year after the crop has been planted. The soils of both series contain considerable sand grains and are plastic, especially the Moca. Both gully and

sheet erosion must be carefully guarded against if these soils are used for pineapples. Gullies from 2 to 3 feet deep (fig. 61) have formed on steep slopes of the Moca soils within 3 months' time. Owing to the wet plastic character of the Moca soils the pineapple beds must have considerable height, and this results in numerous rather deep ditches that are vulnerable to erosion.

Sheet erosion does not affect the yield of pineapples on the Catalina and related soils nearly so much as it does yields of other crops. With the application of rather large quantities of fertilizer, the production of pineapples on soils with a 6-inch surface soil is only slightly higher than on soils with a deep subsoil but with little or no surface soil.

The necessary cultivation in a pineapple field is to keep the surface soil from becoming hard and difficult for the plant roots, water, and air to penetrate rapidly to the subsoil. Weeds must be cut, but after the plant shades the ground very few weeds grow. Nearly all cultivation is by hand. A specially constructed hoe is used, one that has a blade set nearly parallel with the handle so that it can be used to cut the weeds or to stir the soil beneath the long bayonetlike crisscrossing leaves.

The kind and quantity of fertilizer applied at the proper time is most important and probably is the least correctly followed procedure in the growing of pineapples. Different soils need different fertilizers, and the correct quantities to apply can be determined only by long practice and numerous experiments. Some growers use from 1,500 to 3,000 pounds to the acre, applied in about equal quantities in July, September, and January. The formula seems to vary greatly with the different growers. The experiment stations at Río Piedras and Mayagüez should be consulted for the latest information regarding fertilizer formulas for different crops. Owing to the rapid progress that is being made in experimental work of this kind, the growers should keep in constant touch with new developments.

The pineapple crop generally is harvested between March and July, or about 12 months from the time it is planted, unless the plants have been "smoked," a process which hastens their maturity by about 2 months. The smoking process consists of the smothering of burning sticks beneath a canvas tent for a period ranging from 6 to 12 hours. The tents generally cover eight rows, or two beds (fig. 62), for a distance of 200 feet. Sometimes 2 or 3 acres are covered at the same time. The wood is placed in a pile about 2 feet square and is covered with green grass and soil. The advantage of this procedure is to get the fruit on an early and better market. The smoked plants produce ripe fruit during November and December. Smoking the plant prevents almost all of the slips from developing, and for that reason it is a disadvantage, as the buying of slips to start new fields is very expensive. Smoking is practiced in only a few localities and with the Red Spanish variety. The plants on the soils of the coastal plains are smoked during July and those on the uplands during October. The plants will flower within 30 days after being smoked, and the fruits ripen about 90 days later. The cost of smoking is about $25 an acre.

Harvesting consists of gathering the fruits as they ripen and carrying them in baskets (fig. 63) to trucks that haul them to packing sheds (fig. 64), where they are sorted, graded, and crated, and then (generally)

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transported directly to a steamer in San Juan for shipment to United States markets. After the first crop is harvested, a second and third ratoon crop generally is harvested in the 2 succeeding years. Each crop outyields the succeeding crop by about 50 crates to the acre. The first crop on the Bayamón and related soils produces about 250 crates an acre, and the Catalina soils produce about 300 crates.

After the second ratoon crop, the field is plowed, and many farmers on the soils of the coastal plains plant crotalaria for 2 years, in order to assist the soil in building up its nitrogen content. The crotalaria is plowed under, and cane or minor crops occupy the land for a year, after which it is again ready for pineapples. On the Catalina soils many farmers replant the fields to pineapples as soon as the land is plowed. Many farmers on the Mariana soils rest the land a year before replanting to pineapples.

The pineapple plant seems to be similar to the maya plant in that it is attacked by very few pests or diseases. Mealybugs and ants

FIGURE 62.—Smoking a field of pineapples.
Ahumando un campo de piñas.

cause damage in some places. At times the fruit may be infected with black rot which frequently will destroy the center of a pineapple in 24 hours. Some growers paint the butts of the fruit with a commercial preparation of titanium trioxide for the control of black rot. A disease called gummosis affects the fruit in certain districts. The plants are sometimes affected with a chlorotic condition of the leaves. In the most severe cases the plants wither and die. In most places this condition is caused by a very high content of lime in the soil (fig. 65). It can be controlled, except where the pineapples are grown on limestone rock, by adding sulfur to the soil. This method is not economical, however, except in small spots. It is much better to choose land that is acid and adapted to pineapples. In many places the pineapples in narrow strips along the edges of roads surfaced with lime or along highways become chlorotic from the lime blowing directly on the plants or on the soil in sufficient quantity to increase the alkalinity beyond the point tolerated by pineapples. In many places, after heavy rains have washed the lime dust from the plant and leached

the lime from the immediate surface soil, the plants revive and again become green. In some fields where the soils are acid the plants become slightly chlorotic and the fruit becomes reddish pink and poor in quality, resembling the description given for the manganese chlo-

FIGURE 63.—Gathering pineapples on Bayamón clay.
Recogiendo piñas en Bayamón arcilloso.

FIGURE 64.—Pineapple field on Bayamón clay and a plant for packing both pineapples and citrus fruits.
Campo de piñas en Bayamón arcilloso y planta para empacar piñas y toronjas.

rosis of the pineapples grown on some of the soils high in manganese in Hawaii. Farmers have reported that this chlorotic condition, as well as that caused from lime, can be controlled readily by spraying the plants with iron sulfate.

The future possibilities for the production of pineapples are very promising for growers who have considerable capital and know the pineapple business. The production of pineapples on a commercial scale should not be attempted by an inexperienced grower, by a man

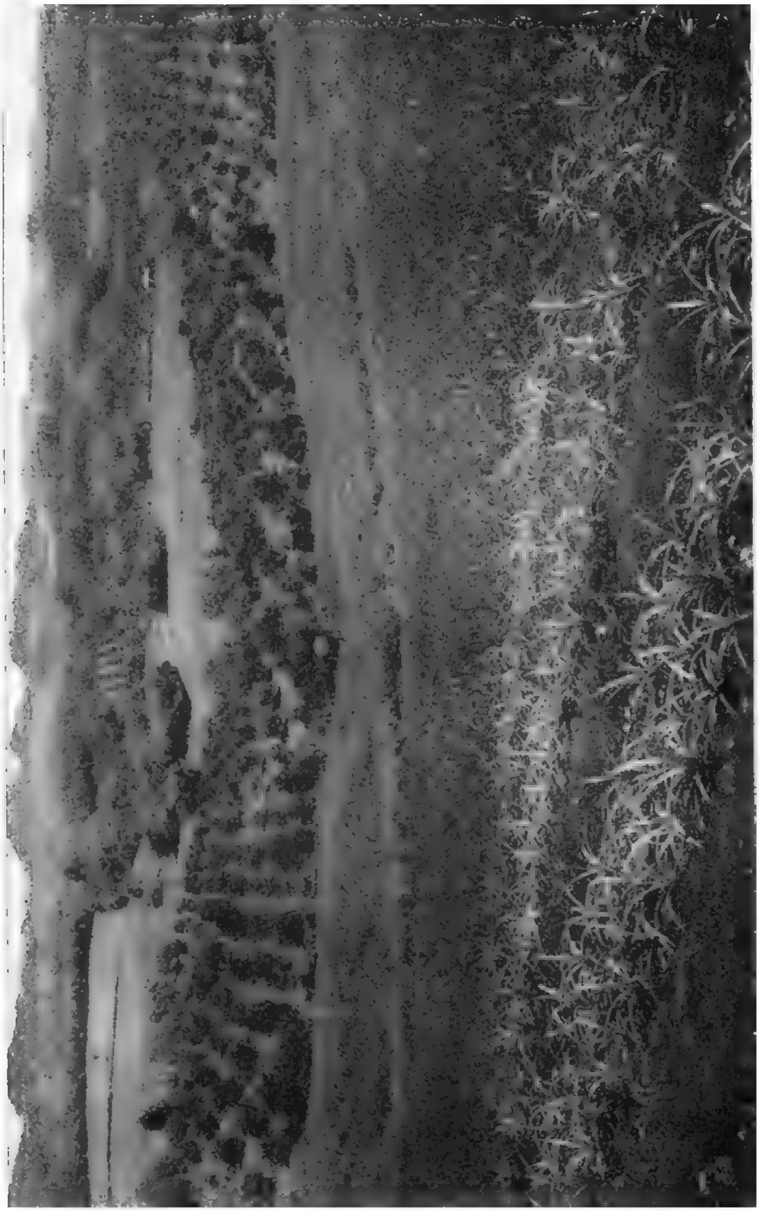

FIGURE 65.—Pineapples affected with chlorosis on a small area of Colinas clay loam. Grapefruit orchards in the distance on the Lares soils.

Piñas afectadas por clorosis en una pequeña área de Colinas arcilloso lómico. Huertos de toronjas a lo lejos en suelos Lares.

with small capital, or on a very small farm. Pineapples require more careful attention than any other commercial crop grown on the island. They are not necessarily hard to grow, nor do they require highly fertile soil, but the successful grower must know the habits of this

plant from the time it is planted until the fruit is sold. According to Henricksen, in El Libro de Puerto Rico by Fernández y García (*17, p. 609*), the cost of producing 258 boxes of pineapples an acre is $994.46. This includes 10,000 slips for seed at a cost of $200, cultivation, planting, fertilizing, interest on land and working capital, taxes, picking, packing, transportation to New York, selling commission, and other expenses. It may readily be seen that with such expense only those growers having considerable capital should attempt to plant this crop. A fairly large acreage is necessary in order to handle the crop more efficiently. On a large farm, slips and suckers for propagation can be produced; thereby the cost of buying slips is reduced. Packing sheds can be built on the large farms, to reduce the cost of crating and packing the fruit.

Considerable profit has been made in growing pineapples during the last few years; this has encouraged the growers to plant many acres. Probably very soon the increased production will lower the price and consequently lower the profit. The acre cost of planting and producing pineapples changes little throughout the years, but the price obtained for the fruit changes considerably. Competition is greater between the pineapple growers in Puerto Rico and Cuba than between the Puerto Ricans and Hawaiians. The canned-pineapple industry undoubtedly will increase in importance in Puerto Rico, and it will help in stabilizing a favorable market.

With the exception of the loss of packing sheds and other buildings on the pineapple farms, the growers of pineapples are not seriously affected by hurricanes. The hurricane risk, however, must be considered with every crop grown in Puerto Rico. Most of the growers of pineapples on all soils except those of the Mariana series, produce several different crops, such as grapefruit, minor crops, and sugarcane. Those on the coastal plains may have a patch of tobacco in addition to the other crops, and all these crops lessen the chances for complete crop failure. Most of the pineapple farms are about 200 acres in size.

COCONUTS (COCOS)

The coconut palm is one of the most picturesque trees along the sandy beaches of tropical countries (fig. 66). Its beauty is surpassed only by its usefulness. The nuts when green are filled with a colorless fluid which is one of the more popular refreshing drinks in Puerto Rico. Usually the coconut water, or agua de coco, is consumed directly from the nut with the husk attached; in recent years, however, the water is mixed with some carbonated water and sold in bottles. When the nuts are matured, a part of the fluid coagulates and forms the white oily meat that is used for desserts, confectionery, and the extraction of oil. The meat is relished by hogs, and when the price is less than $8 or $10 for a thousand nuts, many of the owners of coconut plantations consider it more economical to feed the nuts to hogs than to pay for the cost of gathering, grading, and transporting them.

The husks that protect the nuts are removed at the plantation by skilled laborers in much the same manner as the husks are jerked from ears of corn by a veteran corn husker. The coconut husker stands in one place, and, instead of having a corn hook or peg on his hand, he has a stationary perpendicular sharp-pointed iron bar that is firmly embedded in the soil and extends about 30 inches above the ground.

Each nut is brought down against the sharp metal point with a hard quick blow, then with a quick twist of the nut the husk is split and removed. From 1,000 to 3,000 nuts can be husked in a day by a good husker. The average price paid the husker is $1 for each 1,000 nuts husked. The husks are sometimes sold for the manufacture of brushes and coarse fabrics. The leaves of the coconut palm very often are used in the thatching of the native bohíos and sheds. The long slender erect unbranched trunks sometimes are used for fence posts or are sawed into boards. The lumber produced is fairly durable—more so than is generally supposed.

Coconuts were first taken to Puerto Rico about 1525 from the Cape Verde Islands. Their natural environment is the sandy beaches, and they readily became established. The area that is economically adapted to the production of coconuts is limited to a narrow sandy

FIGURE 66.—Coconut palms growing on Cataño sand along the north coast. Palmas de coco en arena Cataño de la costa norte.

more or less continuous strip of land fringing the coast. The production of coconuts has never been very great, owing to the small extent of land that has the proper soil, climate, and elevation for a more profitable production of coconuts than of any other crop. According to the 1935–36 Annual Book on Statistics, the value of exported coconuts for the years 1902 to 1936 has ranged from a low of $12,720 in 1902 to a high of $1,142,412 in 1920. The value then declined to $152,055 in 1933, and rose slightly thereafter to $306,021 in 1939. Nearly all of the exported coconuts are sent in the shell to the United States. Practically no copra, or the dried meat of the coconut, is exported. The value of exported nuts has ranged from $20 to $45 a thousand. It was $20.36 in 1939.

According to the Puerto Rico Reconstruction Administration census, the number of coconuts harvested in 1910 was 15,568,000; in 1920, 24,608,000; in 1930, 12,003,000; and in 1935, 27,901,000.

Probably three-fourths of the nuts are exported. There were 157,621 bearing palms and 539,243 nonbearing palms in 1935. Assuming that an average of 50 palms are planted to the acre, 13,937 acres, or 3.3 percent of the harvested cropland in Puerto Rico, was in coconuts in 1935. This crop occupied the sixth largest acreage of the cultivated crops during that year.

Figure 67 shows the distribution of coconut palms, as recorded from data of the Puerto Rico Reconstruction Administration census of 1935. The municipalities having the largest number, ranking in the order named, are: Loíza, Carolina, Río Grande, Cabo Rojo, Isabela, and Humacao. These six municipalities produced more than one-half of the coconuts grown on the island. From figure 67 it may readily be seen that most of the coconut palms grow near the coast.

Coconuts grow better and produce higher yields near the sea at low elevations than they do inland at high elevations. For best production coconut palms require a well-drained fairly fertile loose sandy neutral or calcareous soil receiving more than 60 inches of average annual rainfall and being at an elevation of less than 300 feet above sea level. The best coconuts observed during the course of the survey were growing on Cataño loamy sand. Other soils well adapted to coconuts are the well-drained members of the Aguadilla, Cataño, and Meros series; soils of the Maleza, Guayabo, Río Lajas, Palm Beach, and Jaucas series; and coastal beach. Such soils as the sandy-textured types of the river flood plains would be even more productive than the soils just mentioned, but, as they return a high profit when planted to sugarcane, they are rarely planted to coconuts on a commercial scale. The sandy soils, such as the Corozo, Algarrobo, and St. Lucie, are only fair for the production of coconuts. Coconut palms seldom are seen at high elevations. Those that do grow in such places produce a fairly large number of nuts, but they are small and sell for a low price. Palms growing in areas receiving less than 40 inches of average annual rainfall and in which the roots cannot penetrate to ground water produce small nuts of low quality.

Coconut palms will grow at the water line along the beach, but where they are so near the water they are not very productive. They will be stunted or killed in almost all soils having a water table at a depth of less than 18 inches from the surface. They will grow very well if the water table is at least 30 inches below the surface. They can endure rather salty or alkali land; in fact, some experiments show that a small quantity of salt added to the tree roots is beneficial. Coconut palms were growing but not producing nuts on land having 0.9 percent of black alkali in the first foot of soil. Small poor-quality nuts were produced on soils having 0.6 percent of soluble salt, some of which was sodium carbonate.

The mature unhusked and unblemished nuts are used for purposes of propagation. Coconuts are not self-fertilized, and care must be used in the selection of seed to see that both parents are desirable as to quality and quantity of nuts produced. On most plantations the nuts are planted in checkrows about 34 feet apart at a depth slight enough to expose a part of the nut. In some places the seed nuts are first planted in beds and afterward transplanted to the field—in about a year. It takes about 6 months for the seeds to germinate. Very few plantation owners use fertilizer, and very little cultivation is necessary. Regardless of the age of the palms, the space between them

can be and often is planted with pigeonpeas, beans, sweetpotatoes, and yuca. These crops need cultivation, and they are sometimes fertilized, which also helps the coconut palms.

Generally the palms start producing when they are about 6 years old, and they continue to produce for many years. The nuts are harvested about every 2 or 3 months, and the yearly yield for a producing palm is from 40 to 60 nuts. Some palms, however, bear more than 200 nuts a year. An acre of productive palms will produce from 5,000 to 10,000 nuts a year. When the palms begin to produce, the nuts are in all stages of development. Some of the palms are more than 75 feet tall, and it is not easy work for the nut gatherers to climb barefooted to the towering, waving nut-laden crowns. Some of the coconut gatherers use a long slender bamboo pole that has a short sharp knife firmly fastened to one end in such a way that the blade points obliquely downward. A good pull severs the stalk and the nuts fall. Some of the nuts, especially the green ones, are cracked by the fall.

Coconut bud rot is the most serious disease of the palm. This fungus disease attacks and kills the terminal bud, and eventually almost all the leaves drop, leaving the trunk naked. Rats do considerable damage unless metal bands about 10 inches wide are fastened to each tree to a height ranging from 4 to 10 feet from the ground, to prevent the rats from reaching the nuts (fig. 25). The rhinoceros beetle also does considerable damage to young palms.

The chief varieties of coconuts grown are the Green and the Brown, which are produced on both the dwarf and the tall palms.

The future for the coconut-plantation owners is more encouraging than for most of the grapefruit growers. There is, however, considerable risk and uncertainty in the growing of coconuts. The tall palms are easy prey for the more severe hurricanes, and in some places the orchards are completely destroyed during one storm. It requires more than 6 years to reestablish a productive orchard. At present many orchards are still in a more or less abandoned condition from the effects of the serious hurricane of September 13, 1928.

Producing orchards sell for about $300 an acre. They are therefore assessed at a rather high figure, and when the orchard is only partly productive the profit from truck crops and the few nuts produced is used in paying taxes and interest. The expense of handling a productive orchard is low, and if the selling price is favorable good profits can be made.

BANANAS (GUINEOS) AND PLANTAINS (PLÁTANOS)

Owing to the similarity of bananas and plantains they will be discussed together. In Puerto Rico the bananas are about 10 times as plentiful as the plantains. Both are perennial herbaceous plants.

Bananas probably were introduced into Puerto Rico about the time of the first importation of coconuts, or about 1525. Some of the slave-trading ships undoubtedly brought bananas from northern and western Africa. Plantains and bananas are the most important food fruits on the island. Bananas can be purchased at any city market (fig. 68) or local roadside rural store at any time of the year for a very low price. The plantains are more expensive, but they are highly nutri-

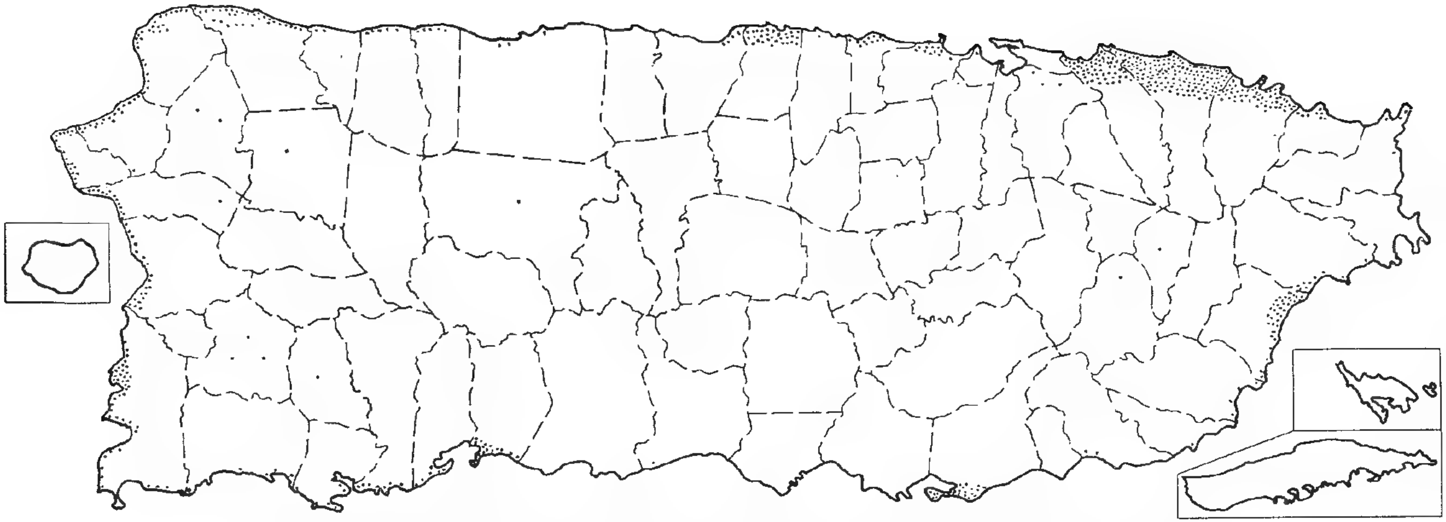

FIGURE 67.—Distribution of coconut palms in 1935. Each dot represents 1,000 palms.
Distribución de palmas de coco en 1935. Cada punto representa 1,000 palmas.

tious and one of the most wholesome fruits grown in Puerto Rico. They constitute an almost indispensable part of the diet of the jibaros.

The banana plant (fig. 69) is developed from an underground stem, or rhizome, called a corm, which sends out shoots that subsequently

FIGURE 68.—City market at Mayagüez.
Plaza del mercado de Mayagüez.

FIGURE 69.—Bananas growing on Catalina clay, where the mean annual rainfall is about 90 inches.

Guineos sembrados en Catalina arcilloso donde el promedio anual de lluvia es alrededor de 90 pulgadas.

develop to form the leafstalks, trunk, or stem. The leafstalk produces a crown of long, broad, umbrellalike leaves. Often, during tropical showers, the leaves are cut from the stalk and are used, especially by boys and girls, as umbrellas for protection against the rain. The entire plant is succulent and has a large area for transpiration.

FIGURE 70.—The flowering stem is produced from the leafy crown, turns downward, and produces a bunch of bananas.

El tallo de flores es producido de la corona de hojas, se vuelve hacia abajo y produce un racimo de guineos.

The flowering stem is produced from the leafy crown, turns downward and produces a bunch of fruit (fig. 70), including from 100 to 200 fingers, or individual bananas. The plantain produces about 35 fingers to a bunch. The bunch is picked green and allowed to ripen in the market or store. The bunches are developed about 10 months from the time the buds appear, or when the plant germinates. After the bunch is gathered the stem, or trunk of the plant, is cut off from

1 to 3 feet from the ground. Fresh shoots or suckers will then appear, and a ratoon crop is produced.

Both bananas and plantains need considerable water, and for the most part they grow in areas of high rainfall. Coffee, bananas, and plantains very often are seen growing in the same district. Coffee is restricted to a narrower range of adaptation than the other two plants.

Figures 71 and 72 show the distribution of bananas and plantains, respectively, according to the 1935 Puerto Rico Reconstruction Administration census. The six municipalities having the greatest number of growing plants of bananas and plantains combined are Lares, Utuado, Orocovis, Adjuntas, Las Marías, Jayuya, and Maricao. The municipalities that lead in the production of bananas do not necessarily lead in the production of plantains. These muncipalities produce about three-fifths of the banana and plantain plants growing in Puerto Rico.

Both bananas and plantains are planted on nearly every soil type, and nearly every rural dwelling has a small patch near the dooryard where the soil is enriched by waste from the house. Yields vary greatly on the different soil types. For best growth and largest production, both plants require a deep, fertile, well-drained soil receiving an average of more than 80 inches of rainfall, well distributed throughout the year, or irrigation. The Catalina, Cialitos, Alonso, Utuado, and similar soils of the humid uplands are well adapted to these plants, and fair production is obtained on the concave slopes or the long, gentle slopes at the bases of the hills. In these areas the soil is much deeper, higher in organic matter, and generally is more moist than on the convex slopes or ridges. Such soils as those of the well-drained or slightly imperfectly drained river flood plains are the best for these crops, but the profit from either bananas or plantains on these valuable soils does not compare with the profit from sugarcane. Low yields may be expected from poorly drained soils, such as those of the Piñones, Coloso, and similar series, as well as from such shallow soils as the steep phases of the Soller, Colinas, Múcara, and similar soils.

The usual procedure for planting either plantains or bananas is to dig holes 18 inches square and about 10 inches deep, spacing them about 9 feet apart each way. The holes are unmolested for at least a week, in order that the soil may become aerated. Just before planting, some of the surface soil is put in the bottom of the holes, and one seed or cutting is inserted in each hole and covered with additional surface soil. Generally the hole is not completely filled artificially but is left open, in order to catch the beneficial run-off water and to act as a catch basin in the control of erosion. From 550 to 650 seeds are required to plant an acre. The seed used are either the sound suckers that protruded from the rhizomes, or fairly large slices containing one healthy bud or eye of a growing plant that has not fruited. Great care must be used in obtaining disease-free, vigorous seed. On most farms the seeds are planted over a period extending from February to August. The soil is cultivated only sufficiently to kill the weeds and to maintain a good tilth. Very few growers fertilize bananas, but some fertilize plantains, as they are more valuable and more profitable. The common practice is to place the first application of fertilizer in the hole with the seed, the second application around the plant 3 or 4 months later, and the third when the fruiting stem appears. The plant produces only one bunch, ordinarily within 11 months from the time of planting. Suckers appear, and the plant can thus survive.

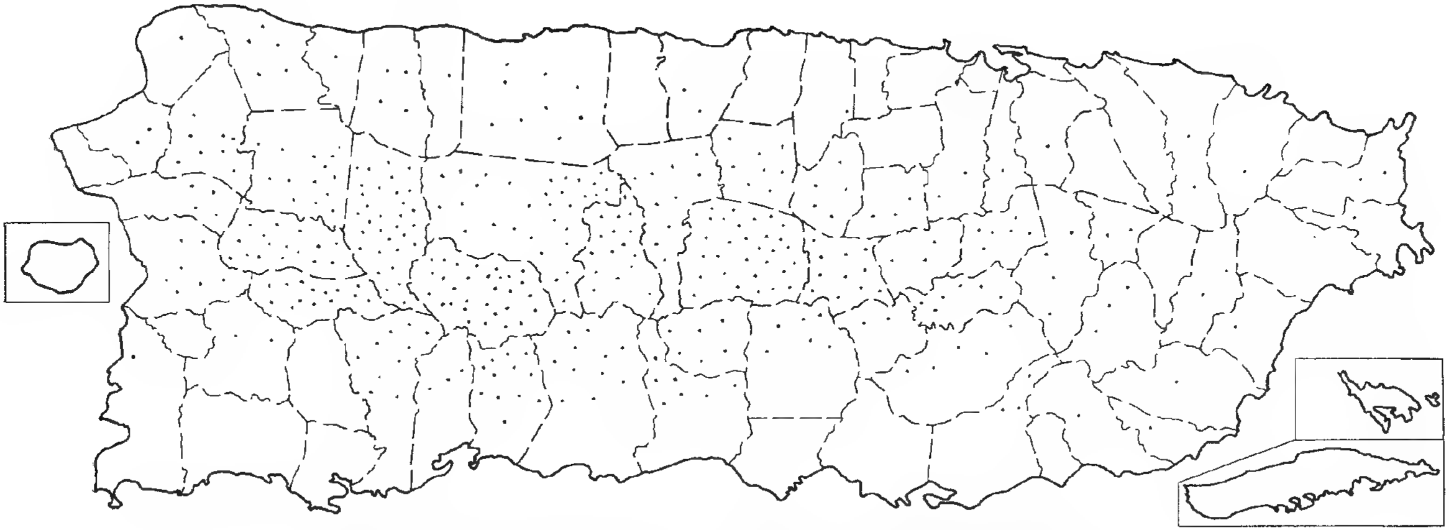

Figure 71.—Distribution of bananas in 1935. Each dot represent 100,000 plants.
Distribución de guineos en 1935. Cada punto representa 100,000 matas.

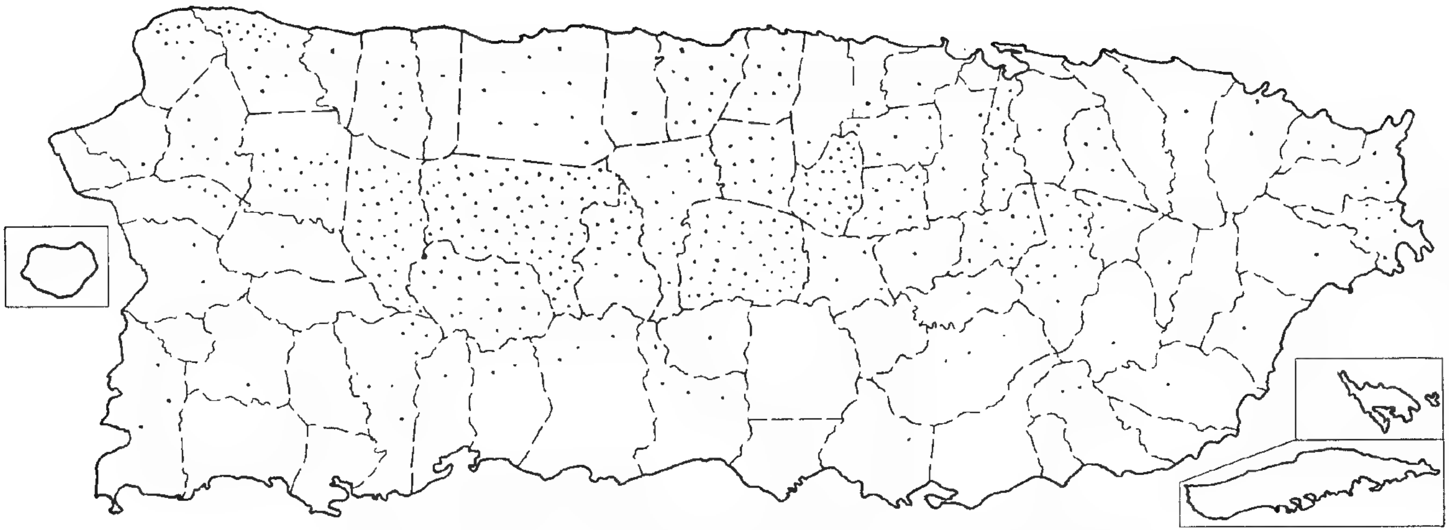

FIGURE 72.—Distribution of plantains in 1935. Each dot represents 10,000 plants.
Distribución de plátanos en 1935. Cada punto representa 10,000 matas.

The acreage in plantains has increased rapidly during the last few years, owing in part to the encouragement given by the Federal Land Bank to the owners of coffee farms, who are seeking to rehabilitate their land. Many small areas are available throughout the island for an increased acreage of both plantains and bananas, and these undoubtedly will be planted in the future. About 8,000 acres are now used in the production of bananas and plantains. Almost $80,000 worth of plantains were imported into Puerto Rico from the Dominican Republic during the fiscal year 1937.

Plantains sell for about 1 cent apiece and bananas for about 5 cents a dozen. Many different varieties of bananas are sold on the market.

The future for the production of bananas and plantains on a large scale is not promising. In order to make much profit on a large-scale production, large areas of well-drained alluvial land should be available, and in Puerto Rico nearly all of such land is now used for sugarcane which brings in greater profit than bananas or plantains under the present economic conditions.

Both bananas and plantains are subject to many diseases and to injury from storms. Probably they always will be important subsistence crops for local consumption.

CORN (MAÍZ)

Probably Puerto Rico has been producing corn for more than five centuries. According to the census of the Puerto Rico Reconstruction Administration for 1935, corn occupies the third largest area of all crops grown on the island. Corn from the 70,217 acres harvested in 1930 produced only 449,016 quintales (which amounts to 801,813 bushels) or about 11 bushels to the acre. Considerable areas that were in corn, however, also produced from 300 to 400 pounds of beans an acre at the same time, and many acres had produced from 600 to 800 pounds of tobacco during the same year.

In 1901 Puerto Rico exported 4,267 bushels of corn to Cuba and 1,843 bushels to the Dutch West Indies (*46, p. 67*). In recent years Puerto Rico has imported nearly one-fourth as much corn as the quantity produced on the island. During 1939, 321,645 bushels were imported, of which only 7,146 bushels came from the United States. Santo Domingo exports large quantities to Puerto Rico, especially from Puerto Plata. Recently the total value of corn meal imported has almost equaled or exceeded the value of imported corn.

Figure 73 shows the distribution of corn as recorded by the Puerto Rico Reconstruction Administration census of 1935. It may readily be seen that the largest acreage of corn correlates fairly closely with the area having the largest rural population. This bears out observations made in the field. Nearly every rural dwelling, except the ones located on land valuable for the production of sugarcane, has a small corn patch nearby, very often on very steep land as seen in figure 108. Corn is not grown on land that is well adapted to sugarcane or grapefruit, on irrigated land, or on the best soils of the island. The municipalities having the largest acreage in corn, ranking in the order named, are Cabo Rojo, Isabela, San Lorenzo, Yauco, Coamo, and Lajas.

The cornfields, with the exception of those in the southwestern part of the island, are small, are of irregular shape, and are managed en-

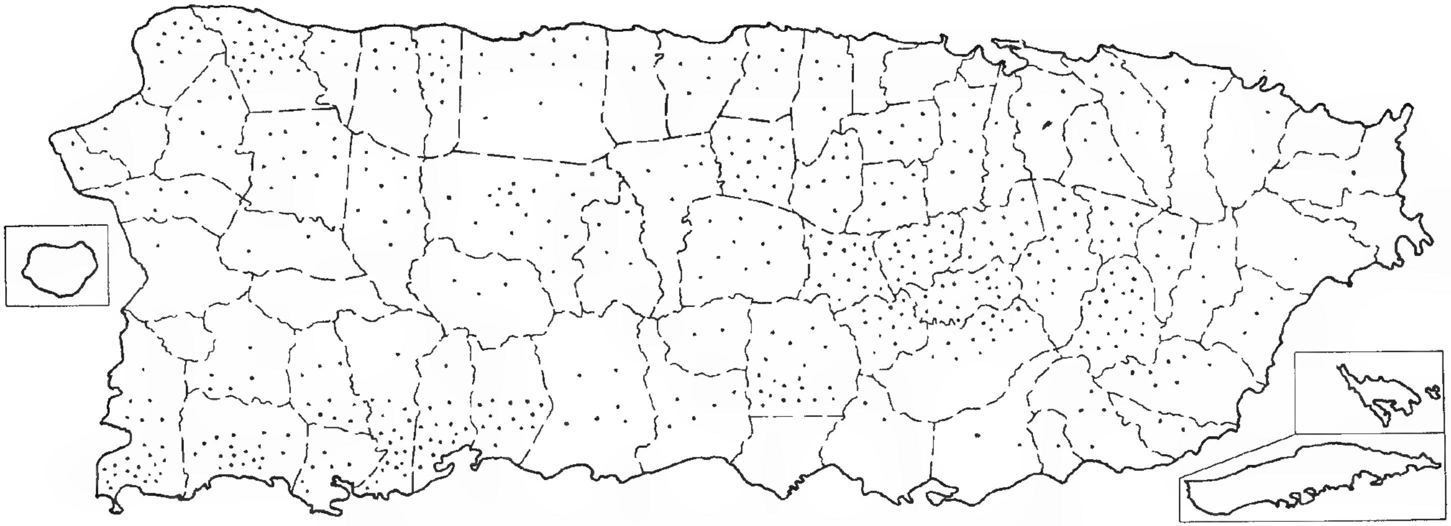

FIGURE 73.—Distribution of corn in 1935. Each dot represents 100 acres.
Distribución de maíz en 1935. Cada punto representa 100 acres.

tirely by hand labor. In the vicinity of Parguera and Peñuelas, the fields range in size from 5 to 30 acres and are more or less rectangular or square. Here some machinery is used in the preparation and cultivation of the land. These fields are owned and operated by owners of large ranches. In this district considerable areas of the Fraternidad soils that are not irrigated are planted to corn. The land is first plowed with oxen, then harrowed, and furrows are made about 4 feet apart. From 10 to 15 pounds of seed are planted to the acre. Seeding is done by hand, usually in September or October. The corn is harvested in March and April. The pickers, often from 6 to 10 in one small field, pick and husk the ears and throw them in piles on the ground. Later the ears are loaded into oxcarts and hauled to bins on the ranches. In this area the principal variety grown is Blanco de Cabo Rojo which yields from 20 to 30 bushels to the acre on the Fraternidad soils during favorable years and from 10 to 15 bushels on the more sandy soils, such as Maleza loamy sand and Guayabo fine sand. On many farms squash (calabaza) is planted between the corn rows. Very little fertilizer is used. Most of the corn grown here is consumed by the large dairy and range herds that are prevalent throughout this district.

Much of the corn produced in small fields in the humid sections is planted in holes, immediately following the last picking of the tobacco leaves, early in December. About four kernels of the native seed are planted in each hole, and the holes are spaced 3 by 2 feet. Beans frequently are planted between the corn rows, and both crops obtain some benefit from the fertilizer applied to the tobacco crop recently harvested. All cultivation and weeding is done by hand labor with hoes and short-handled pickaxes. Corn in the humid areas produces from 5 to 15 bushels to the acre, and most of it either is fed to chickens and pigs or is ground in small stone hand-operated mills for corn meal.

The native corn has small kernels and thick short cobs. The principal insects injuring corn are the corn earworm, cornstalk borer, and aphid. In some areas the cornstalk borer is the limiting factor in corn production. In the semiarid section near Parguera, giant milkweed and sandburs are the most troublesome weeds in the cornfields.

Corn always has been and probably always will be an important crop for the jibaros who grow subsistence crops. It fits in conveniently with their yearly crop rotation of tobacco, corn, and beans. The selling price of corn ranges from $1.25 to $2.50 a hundred pounds. The acre yield could be doubled easily in the humid section if better varieties of seed were planted and applications of fertilizer made. The adoption of better varieties of sweet corn also should be given more consideration than it has been given in the past. More sweet corn should be grown and consumed by the laboring classes.

SWEETPOTATOES (BATATAS)

When the Spaniards arrived in 1493, sweetpotatoes were grown fairly successfully by the Arawak Indians on the alluvial lands of the Yabucoa Valley and elsewhere. This plant probably came into Puerto Rico by way of the Venezuela-Trinidad route during early intercourse among the Indian tribes.

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This is the most widely planted root crop in Puerto Rico, and, according to the Puerto Rico Reconstruction Administration census for 1935, 36,947 acres, or 5.2 percent of the harvested cropland of the island, were planted to this crop. It rates sixth in acreage of all crops planted. The acreage of sweetpotatoes has varied in different years. There was a considerably larger acreage in 1929 than in either 1919 or 1935.

Figure 74 shows the distribution of sweetpotatoes according to the 1935 Puerto Rico Reconstruction Administration census. It may readily be seen that this plant is closely associated with areas where the rural population is dense (fig. 21). It is widely planted throughout the island, but the concentration seems to be greater in the municipalities of Isabela, Utuado, Arecibo, Cidra, Morovis, and San Lorenzo than in any other municipality. This crop, like many of the other subsistence crops, can be planted on almost any soil type at any time of the year in any part of the island, without complete failure. For best production, however, the soil should be reasonably fertile well-drained fairly deep loose sandy loam or loamy sand. A very good growth of vine is produced on rich alluvial loams, clay loams, and clays and on some of the heavy clay upland soils, but the best production is obtained on Cataño loamy sand, Maleza loamy sand, and similar soils. These soils produce from 6,000 to 7,000 pounds to the acre. The acre yields of other soils are as follows: Cayaguá sandy clay loam, 4,000 to 5,000 pounds; Alonso clay, smooth phase, 3,000 to 4,000 pounds; Utuado loam, smooth phase, 2,000 to 2,500 pounds; Sabana Seca sandy clay loam, 1,500 to 1,700 pounds; Múcara silty clay loam, 1,000 to 1,200 pounds; and Colinas clay loam, 800 to 1,200 pounds. It is not an unusual sight to see sweetpotatoes growing on Tanamá stony clay, where the only visible soil is in little pockets or crevices in the rocks. Such soil produces very low yields, but almost every bohío has a small patch of sweetpotatoes planted in the garden, even where the surface is almost all bare rock.

The selling price of sweetpotatoes is about 1 cent a pound, and they can be purchased at any of the city markets or at the rural roadside stores at any time of the year. They can be kept for a long time if properly stored in a cool dry place, preferably in the ground and covered with loose sandy soil.

The usual procedure for planting sweetpotatoes is to stir the ground to a depth of 6 inches with a walking plow or a hoe, then to make ridges about 6 inches high, 2 feet wide, and 3 feet from center to center. Either the stems of healthy plants or clean disease-free slices of the roots are used for seed. If the stems are used, pieces from 16 to 24 inches long are buried about 3 inches deep in the center of the ridges. The cuttings are spaced about 2 feet apart. If the roots are used, about 10,000 slices are needed to plant an acre. Sweetpotatoes may be planted at any time, but preferably during wet weather when the soil is moist. In the tobacco district near Cayey and San Lorenzo, the sweetpotatoes are planted after the tobacco is harvested. Very few farmers apply fertilizer to the sweetpotato crop, and little or no cultivation is necessary after the vines are large enough nearly to cover all the bare ground. This is a fairly good crop to prevent sheet erosion on steep hillsides, especially after the plants have attained a fair size.

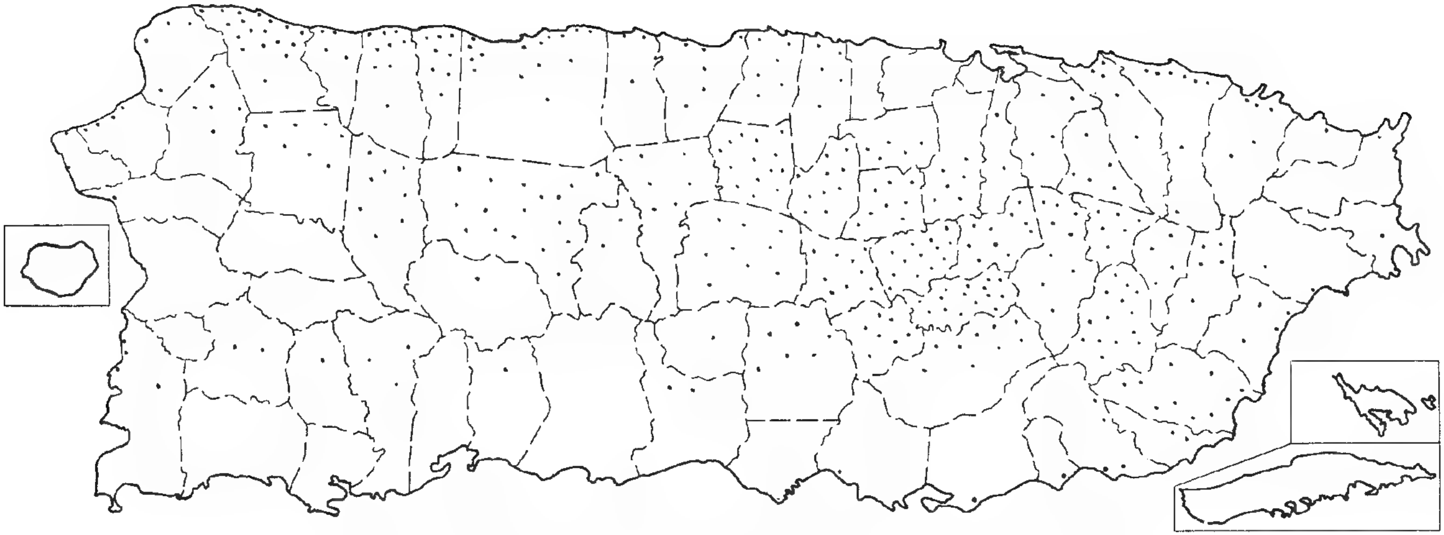

FIGURE 74.—Distribution of sweetpotatoes in 1935. Each dot represents 100 acres.
Distribución de batatas en 1935. Cada punto representa 100 acres.

The crop is harvested at a time ranging from about 4 to 6 months after planting, depending on the variety grown. The principal varieties are Key West(a white variety) and Mameya (a yellow variety).

Owing to the increasing population, the acreage in sweetpotatoes undoubtedly will increase. Sweetpotatoes are relished by nearly all Puerto Ricans, and, supplemented with other subsistence crops, are the staff of life for many thousands of people. Sweetpotatoes are easily and cheaply grown, and they do fairly well on land that is too poor for most of the other subsistence crops. Sweetpotatoes are fairly tolerant to "alkali" soils—more so than most other subsistence crops, except bananas.

Disease is not a limiting factor in the growth or production of sweetpotatoes, as they are comparatively free from pests and diseases. Yields would be greatly increased if the ground were properly fertilized with from 300 to 600 pounds of complete fertilizer, such as a 4 8 -10 mixture, and if only pure or high-grade seed were used.

YAUTIA, DASHEEN, OR TANIA (YAUTÍA)

Yautias were grown successfully by the native Indians when the Spaniards landed in 1493. The yautia probably is one of the oldest cultivated crops of tropical America. Several species of uncultivated yautia (dasheen), commonly known as malanga, grow along the island's shaded stream courses and the moist areas at the heads of drains. The tubers of the cultivated varieties are nutritious and palatable when properly prepared. The entire production is consumed locally. Sometimes the large rootstock is eaten, as are also the leaves and rhizomes. The tubers are more or less cylindrical or oval and range from 4 to 8 inches in length. Different varieties have different shapes and colors—they may be white, red, or yellow. The tubers are prepared for eating in as many different ways as are potatoes. When the rootstocks are used, they generally are boiled. The young leaves are stewed as greens. Flour is sometimes made by grinding dried slices of the tubers. It may readily be seen that the yautia is a valuable plant for the poorer people. Fortunately the plant is not seriously attacked by insects or plant diseases, and it will grow and produce fair yields on nearly every soil type if the rainfall is sufficient. The production, however, varies considerably, according to soil and moisture conditions. For best results, yautias require a rather deep fertile medium heavy soil that is slightly poorly drained or receives a high yearly rainfall. On such soils as those of the Yabucoa, Coloso, and Fortuna series, the production ranges from 8,000 to 10,000 pounds to the acre. Yields on less desirable soils are considerably below 8,000 pounds. A production of 2,000 pounds is a good yield for such shallow soils as the Múcara, Tanamá, and Colinas. Such soils as the Catalina, Cialitos, Bayamón, and similar soils produce an acre yield ranging from 3,000 to 5,000 pounds. The sandy soils, such as the Aguadilla and Cataño, yield 4,000 to 6,000 pounds.

At any time of the year a small patch of yautias may be seen growing very close to nearly every rural dwelling in the humid and subhumid areas. The plants are planted promiscuously in many places along shaded ravines and moist spots, but on the hillsides the common practice is to dig 10-inch cup-shaped holes spaced 2 feet apart and to insert one or two small tubers or a part of the top of the old root-

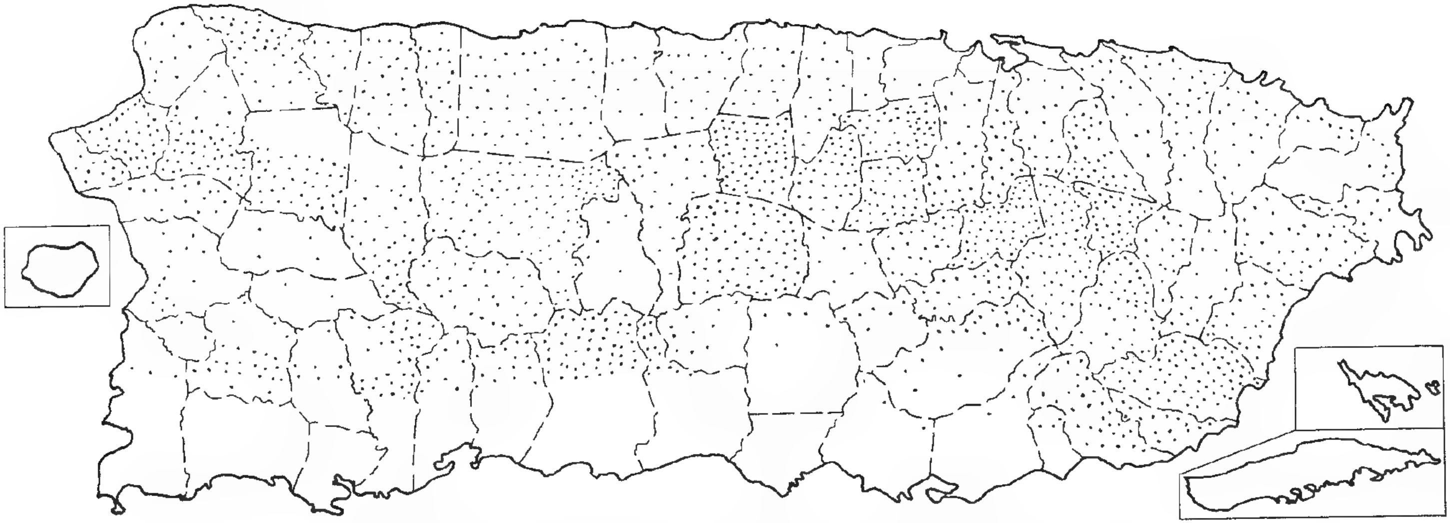

FIGURE 75.—Distribution of yautias in 1935. Each dot represents 10 acres.
Distribución de yautías en 1935. Cada punto representa 10 acres.

stock. The hole is then about half filled with soil. Wash from the hillsides eventually will fill the holes, replenish the organic supply, and add more moisture to the plant than if the plant were set flush with the ground. The holes serve as effective catch basins in preventing erosion as they check the force of the run-off water.

All cultivation is performed by hand labor, and very little fertilizer is used. Farmers who apply fertilizer use a 6–8–10 or 6–10–15 mixture, and about 1,000 pounds to the acre in two applications—the first 500 pounds after the first cultivation and the second 500 pounds about 5 months later.

Yautias are harvested from 8 to 12 months after the date of planting, depending on the varieties planted. The principal varieties grown are Blanca, Amarilla, Filipina, and Kelly. The Blancas probably are the most common, but the Amarillas are the most productive and the most preferred. The usual method of harvesting consists of pulling the leafstalk and digging the tubers that are not exposed, in much the same manner as potatoes are dug by hand labor. The composition (*4, p. 23*) of yautias compares favorably, especially in protein and carbohydrates, with that of either potatoes or sweetpotatoes. The fat content is less than in sweetpotatoes but greater than in potatoes. Yautias contain many more calories than potatoes but slightly less than sweetpotatoes.

Figure 75 shows the distribution of yautias in Puerto Rico, according to the 1935 Puerto Rico Reconstruction Administration census. It may readily be seen that this plant has a wider distribution throughout all the humid parts of the island than any other root crop.

The municipalities having the largest acreage in yautias are Utuado, Orocovis, Yabucoa, Morovis, Caguas, Aguas Buenas, and Arecibo. Most of these municipalities also have a large acreage in other subsistence crops. Generally speaking, soils and climate well adapted to coffee are also well adapted to yautias. Yautias, however, have a somewhat wider soil adaptation, as they grow very well on poorly drained soils.

The price of yautias is generally about $1.75 a hundred pounds. The price is usually less than that paid for ñames, corn, or pigeonpeas but it is greater than the price of sweetpotatoes and yuca.

The production of yautias in the future probably will be as high or higher than it has been in the past. According to the 1935 Puerto Rico Reconstruction Administration census, yautias occupied 17,596 cuerdas on the island, or 2.5 percent of the land from which crops were harvested in that year. They held the eighth place among the cultivated crops. As yautias thrive on imperfectly drained soils, it is possible that, with the use of excellent varieties and proper fertilizer, some of the poorer land on the coastal lowlands now producing low yields of cane can be utilized for this crop, thereby increasing the production of a crop that is consumed entirely on the island.

ÑAME, OR YAM

Ñames were introduced into Puerto Rico some time between the sixteenth and seventeenth centuries, and, owing to the favorable frost-free moist climate and deep soils, also to the fact that the roots are relished highly by the native people, the acreage rapidly increased. This is now one of the important root crops used for food by the Puerto Ricans, and nearly all the crop is consumed on the island.

The edible part of the ñame is the brown thick-skinned more or less cylindrical root, or tuber, which may weigh as much as 30 pounds. The interior of the ñame root is very similar to the potato, as it is white, firm, and starchy. It should be used when fresh. According to Kinman (*26, p. 12*), one of the most common varieties grown in Puerto Rico has more than 24 percent of starch in the fresh roots. Ñames have a high food value, and they are easily prepared in a number of different ways for table use.

The above-ground part of the plant resembles somewhat a very dense-leaved morning-glory vine. It requires an artificial support and may climb to a height of 8 feet.

Figure 76 shows the distribution of ñames in Puerto Rico. A very close similarity in area exists between the distribution of ñames and that of yuca. The production of ñames increased rapidly between 1929 and 1935, especially in the eastern part of the island. According to the 1935 Puerto Rico Reconstruction Administration census, the leading municipalities in which ñames are grown are Moca, Aguada, Yabucoa, San Sebastián, Isabela, and Utuado. The greatest concentration of land in ñames is along the highway between Moca and San Sebastián. This area receives a yearly rainfall ranging from 80 to 110 inches, and the soils in which the ñames are grown are red, acid, and fairly fertile, such as those of the Moca and Lares series. The smooth areas of the Catalina soils also are well adapted to ñames. In the municipality of Isabela the ñames are grown on the permeable deep Coto, Maleza, and Matanzas soils. Rainfall within this latter area is not sufficient for maximum production, and irrigation would increase the yield nearly twofold.

Ñames can be planted at any time during the year, but most farmers in the humid sections or within the irrigation districts prefer to plant during the winter and spring. In advance of planting, round-topped ridges about 5 feet apart and 1½ feet high are constructed, either with a plow or by hand labor. It is necessary to have fertile loose soil high in organic matter near the top of the ridge. Rather large seed pieces of good healthy ñames are selected for propagation. The seed pieces are very similar to the seed pieces of potatoes. Generally a 5- or 6-ounce cross section of a well-developed cylindrical root produces the highest yields. In many places the seed pieces are planted about 18 inches apart along the tops of the ridges at a depth of about 3 inches, and some growers prefer to plant them in hills spaced about 2 by 2 feet.

About 3 ounces of complete fertilizer, such as a 6–9–12 mixture, is applied in each hill about the time the seed germinates, and a second application of an equal quantity is applied about 4 months later.

The cultivation necessary is to keep the ridges in good loose condition and to destroy the weeds. These operations are accomplished with either a machete or a hoe. It is necessary for the growing vines to have a trestlelike support which often is made from post and wire.

At the time of the first harvest, usually about 8 months after planting, the soil is loosened and the large edible ñame root is severed from the crown. The void space is filled with loose fertile soil and many buds develop from the crown and produce a second supply of edible roots within about 4 months.

The main varieties grown are the Ñame de Guinea, Ñame Papa, Ñame de Agua, Ñame de Guinea Blanco, and Ñame de Mapuey.

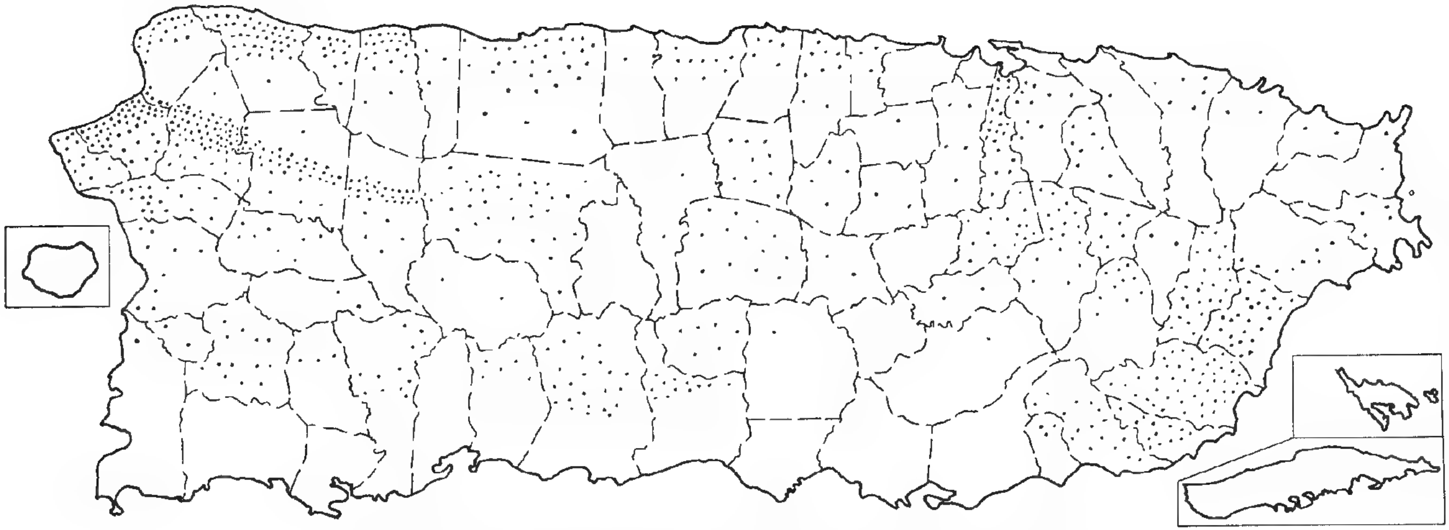

FIGURE 76.—Distribution of ñames in 1935. Each dot represents 10 acres.
Distribución de ñames en 1935. Cada punto representa 10 acres.

Ñames are practically free from insects pests and plant diseases, and this probably is one reason that they are so widely cultivated. They can be grown on many soil types in the humid areas, but by far the largest acreage devoted to their culture is on the well-drained deep acid soils such as those of the Moca, Lares, Fajardo, Catalina, Alonso, Cialitos, Bayamón, Coto, and similar series.

The production ranges from 8,000 to 12,000 pounds an acre on the Lares, Moca, Fajardo, and the better areas of the Catalina soils. The steep areas of the Catalina and Cialitos soils produce from 2,000 to 3,500 pounds an acre. The Coto, Bayamón, and similar soils of the valley coastal plains produce about 6,000 pounds an acre unless the land is irrigated or receives an average of more than 78 inches of rainfall a year. With irrigation, the yield is nearly doubled.

Ñames would grow very well on almost all of the well-drained alluvial soils, such as those of the Toa, Estación, and Viví series, but they cannot compete in profit with sugarcane on these soils. The best of these soils probably would produce more than 28,000 pounds to the acre. The shallow soils of the Múcara, Colinas, and similar series are not well adapted to the large roots of the ñame plants; therefore the production from these soils ranges from only 1,000 to 2,000 pounds an acre. Poorly drained soils of the coastal lowlands or river flood plains and the soils in the nonirrigated arid sections are not used for this crop. A very small area of the sandy soils of the coastal lowlands is planted to this crop, as these soils are only fair for the growing of ñames. The future of the production of ñames is very encouraging, especially for the grower of subsistence crops. As good ñame seed is rather expensive, the large tracts are planted by the more progressive landowners. Considerable extension work could profitably be made by giving advice and aid in fertilization, proper methods of planting, cultivation, harvesting, seed selection, and marketing of the ñames grown by the owners of small tracts.

The selling price of ñames ranges from $1 to $2.50 a hundred pounds, and the income to the acre from this crop is higher than that from any other crop commonly grown by the jibaros.

PIGEONPEAS (GANDULES)

The exact origin of the pigeonpea seems to be unknown. According to Sturtevant (*39, p. 125*), pigeonpeas were found in some of the Egyptian tombs of the twelfth dynasty (2200 2400 B. C.). It is not known when they were introduced into Puerto Rico; probably they came from Africa on some of the slave-trading boats. Pigeonpeas have been one of the leading protein foods of the Puerto Rican jibaros for many centuries. Numerous varieties are planted throughout the island; the most common are Gandul Blanco, New Era, and Gandul Guisante.

Pigeonpeas grow on tall slender perennial bushy shrubs that range in height from 4 to 10 feet, depending on the variety, soil, and climate. The seeds are produced in long slender rounded or flattened pods, and usually they are gathered before maturity and are prepared for cooking either alone or with rice. The fresh green seeds have a high nutritive value and are highly relished by the natives. The matured shelled peas, as well as the fresh green peas, can be purchased

in nearly every town market at any time during the year. The average price for a hundred pounds is about $2.50. This is more than the price of an equal quantity of corn, yuca, or yautia.

Nearly every rural home, as well as many city residences, has a small cluster of bushes in the dooryard or near the dwelling. Thus the needs of the family are supplied, and possibly there is some surplus for sale. Pigeonpeas are planted also in rows, in many places along the division lines of landowners, or as windbreaks in young grapefruit orchards. The plant is a legume and is sown by many farmers to enrich the soil, as the nodule-producing bacteria grow abundantly on the well-developed root system.

This plant, like most leguminous plants, prefers a neutral or alkaline well-drained deep soil for highest yields and best quality of seeds. Fortunately it produces fairly well on shallow neutral or very slightly acid soils, such as the Múcara, that occur in areas where the rural population is dense. Although pigeonpeas can endure long droughts, they will grow under a great variety of climatic conditions as well as on many kinds of soils.

Figure 77 shows the distribution of pigeonspeas as recorded from data of the Puerto Rico Reconstruction Administration census for 1935. The municipalities having the largest acreages, ranking in the order named, are Yauco, Isabela, Peñuelas, San Sebastián, Moca, Lares, Aguada, and San Germán. It may readily be seen that this crop is concentrated to a great extent in the extreme northwestern part and the southwestern part of the island. The land in these sections is either fairly dry or there is a considerable area of soil that is not very productive for cash crops, therefore minor crops occupy a fairly large acreage. The population also is very dense in these places, except in the extreme southern part. Only a small acreage is devoted to this crop on the red acid soil in the center of the island, where the rainfall is high. The pigeonpea, although a drought-resistant plant, will grow luxuriantly in humid sections on alkaline soils, provided the land has good surface drainage. It grows very well on the alkaline Soller soils in the vicinity of San Sebastián where the average annual precipitation exceeds 100 inches. In the same vicinity, pigeonpeas growing on the acid Catalina, Lares, or Moca soils do not have a healthy appearance and do not produce a high yield. The leaf growth in general is fairly dense on the plants growing on these soils, but they lack the bright green color noticed on plants growing on neutral or slightly alkaline soils.

In Puerto Rico the pigeonpea pod is used almost exclusively for human consumption. In other countries, especially Hawaii, both the plant and the pods are used with excellent results as forage for livestock.

Almost all of the pigeonpeas are grown in very small patches by the jibaros, and the general procedure is to loosen the ground with a hoe or pickax, then make square holes spaced about 30 inches apart in rows 3 or 4 feet apart. The planting season is from March to May, and the common practice is to place three seeds in each hole. About 5 pounds of seed to an acre are used. Only good clean seeds free from disease and injury by insects should be planted. The planted seeds are covered with soil to a depth of about 2 inches. Very few planters fertilize this crop, and the only cultivation necessary is to kill the weeds and keep the roots covered. Most of the land planted to

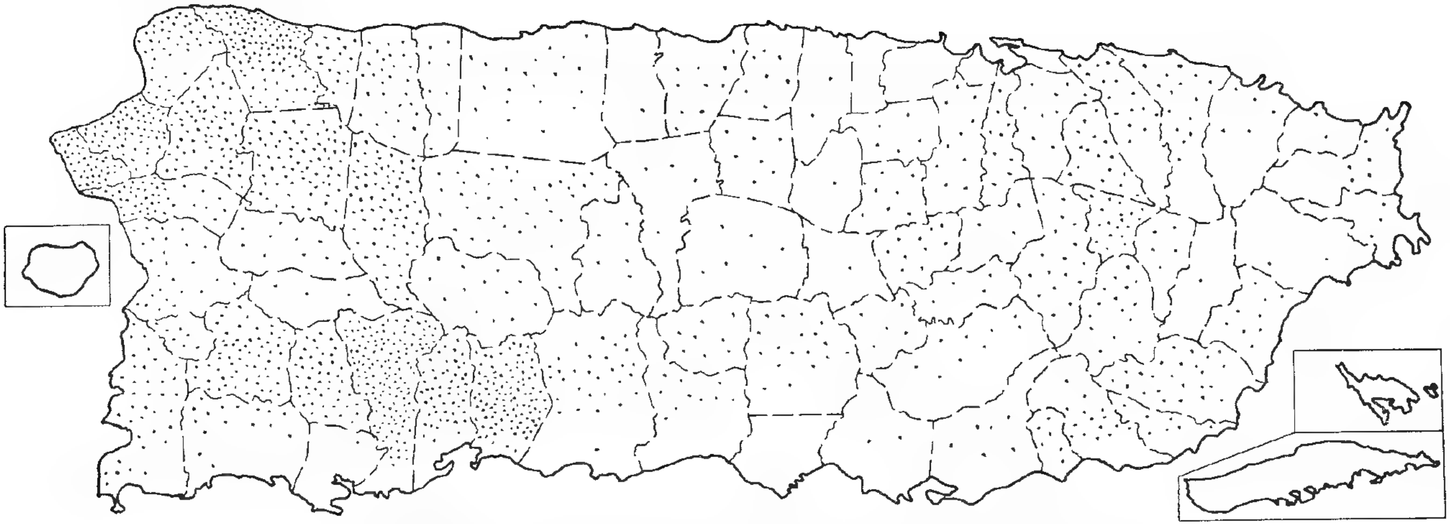

Figure 77.—Distribution of pigeonpeas in 1935. Each dot represents 100 acres.
Distribución de gandules en 1935. Cada punto representa 100 acres.

this crop has undergone considerable surface erosion, and much of the loose surface soil has been washed away from hills having more than 25-percent slope. Many patches of pigeonpeas are planted on 80- and 100-percent slopes.

Harvesting consists of picking the pods about 7 or 8 months from the time of planting and again in 6 or 7 months. The acre yield is very low compared with that in Hawaii. A yield of 300 pounds an acre is considered a good crop on such soils as the Múcara, Descalabrado, Colinas, and similar soils. From 150 to 200 pounds are obtained from acid red upland soils, such as the Catalina and Cialitos. The sandy Cataño and Aguadilla soils yield from 250 to 400 pounds. Lower yields are produced on the Sabana Seca soils and very low yields on the Corozo soils. Such soils as those of the Toa are the irrigated areas of the San Antón series probably would yield more than 4,000 pounds of shelled peas under proper management.

According to the 1935 Puerto Rico Reconstruction Administration census, 15,954 cuerdas, or 2.2 percent of the cultivated land from which crops were harvested, were in pigeonpeas in 1935. This acreage undoubtedly will increase in the future because: (1) The increasing population will need more food, which can be furnished by the palatable, nutritious, and easily grown pigeonpeas; (2) large areas of soils have lost, through leaching and continuous cultivation, essential plant nutrients, which eventually must be replenished by a cover crop, such as pigeonpeas; and (3) the installation of better canning factories and wider advertising of the value of canned pigeonpeas may be expected to increase the demand for them for export. According to Barrett (*5, p. 349*), pigeonpeas are high in iron and iodine. Owing to the large quantity of pigeonpeas consumed by the people of Puerto Rico it is possible that they obtain sufficient iodine to help prevent the growth of goiters. Very few cases of this disease were noticed on the island, but it has not been determined whether this is due to the large quantity of pigeonpeas consumed or to some other cause.

Pigeonpeas are relished by chickens and nearly all domestic animals. Krauss (*27, p. 34*) states that in Hawaii cattle fed wholly on pigeonpea pasture gained from 1½ to 2¾ pounds a day. The carrying capacity of a good field ranges from 2 acres to one head to 1 acre to one and a half head. It would seem that this plant should be used to much greater extent as a forage crop in the semiarid sections. It grows well on the Rosario and Nipe soils, two of the most infertile soils on the island. Such soils could be made more productive by growing this leguminous crop, and at the same time good pasture could be produced in places where only cacti and nearly worthless thorny bushes are growing now. The seeds of the pigeonpeas are relished by wild pigeons and other birds. The pigeonpea plant is an important source of honey, judging from the number of bees seen near the flowers.

Yields could be greatly increased by the use of fertilizer and by the control of insects and diseases. Very little attention has been given to the damage done by insects and diseases, but, judging from the number of inferior and shriveled pods in nearly every large cluster of bushes, the loss from fungus disease and insect injury must be great. Weevils are destructive after the seeds are gathered.

YUCA (CASSAVA)

Yuca is probably a native of Brazil and was imported into Puerto Rico many centuries ago. It was one of the main if not the main food crop of the Arawak Indians when the Spaniards discovered the island.

Although the yuca is a quasi-perennial plant, it nearly always is used as an annual. It is a shrubby, woody plant ranging from 4 to 10 feet in height. The stems are used for propagation. They are long, slender, and noded. The starchy tuberous roots are the only edible part of the plant. Several varieties of yuca are cultivated, but they commonly are referred to as either the "sweet" kind or the "bitter" kind. There is probably no botanical distinction between the two. The bitter kinds are used mostly for starch and tapioca flour, and the sweet ones are prepared for eating by boiling, baking, and frying. In some places the sweet yuca tubers are fed to livestock with very good results.

Some varieties, especially the bitter ones, contain considerable prussic acid which may be fatal if the tubers are eaten raw or after they have been dug for several days. Cooking the fresh tubers eliminates the danger of poison. Figure 78 shows the distribution of the yuca plant according to the Puerto Rico Reconstruction Administration census of 1935. This plant is fairly well distributed, and there is a concentration of plants in areas where the rural population is dense. The municipalities having the largest acreage in yucas, in the order named are: Isabela, Moca, Aguadilla, Camuy, and Loíza. All except Loíza are in the northwestern part of the island.

The yuca will grow and produce fairly good yields on a wide range of soil types and under diverse climatic conditions, but it cannot tolerate frost or waterlogged soils. The soils most commonly used for the growing of this plant and the average acre yields without fertilizer are as follows: Cataño loamy sand, 3,000 pounds; Maleza loamy sand, 2,800 pounds; Matanzas clay, 2,500 pounds; Vega Alta clay loam, 1,500 pounds; Catalina clay, 1,400 pounds; Múcara silty clay loam, 1,200 pounds; and Cayaguá sandy clay loam, 1,000 pounds. Similar soils produce accordingly. The level well-drained alluvial soils would produce considerably more than 8,000 pounds to the acre, but, as the land is more productive for cane, practically no yucas are grown on these soils.

The usual procedure for planting yuca is to loosen the ground with a hoe or with a walking plow to a depth of about 8 inches. Shallow furrows are then made, and fresh cuttings about 7 inches long of the middle part of sound stems having two or more eyes are inserted in the furrows in a slanting position and are covered with soil to a depth of about 4 inches. Some growers cover only about one-half of the cutting. The plants are spaced about 1½ or 2 feet apart in rows 4 feet apart from center to center. The planting can be made at any time during the year, but most farmers prefer to plant just before the rainy season. The young plants are cultivated frequently, but after they have grown to a fair size, the leaves and branches shade the ground, and weeds cannot thrive. Very few farmers use fertilizer on this crop.

The tubers are gathered with a hoe or a spade, from 8 to 10 months after planting. When the plant begins to flower, the tubers are considered mature enough for cooking purposes. The tubers to be used for food should be fresh. Considerable quantities are peeled, cut

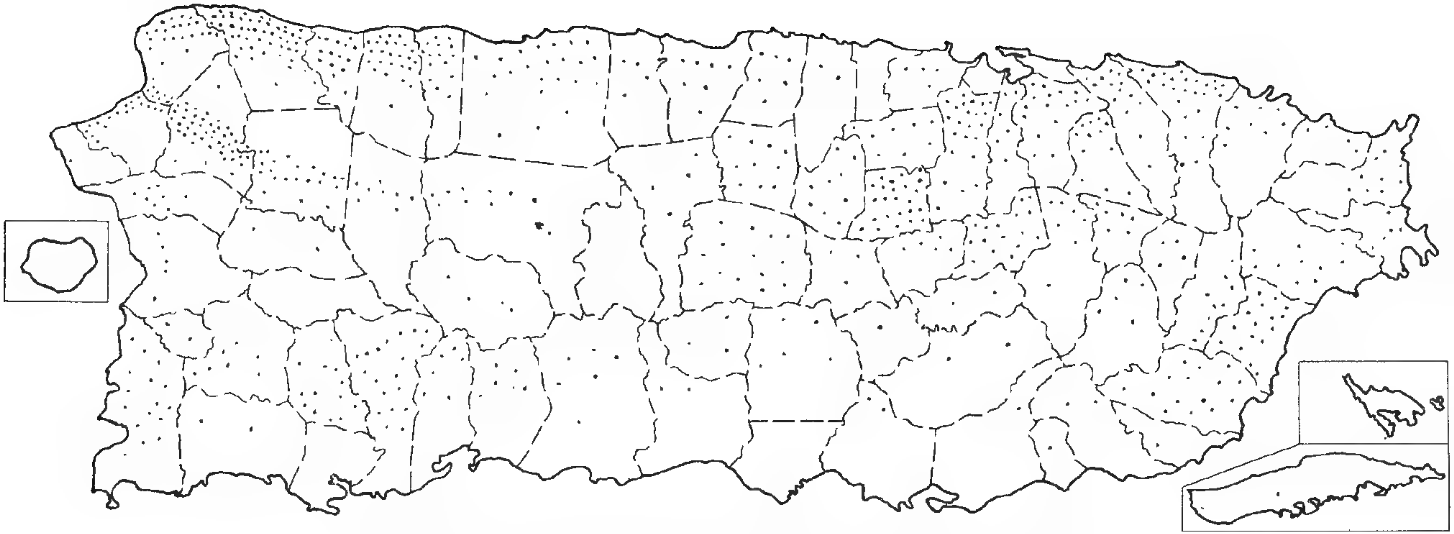

FIGURE 78.—Distribution of yuca in 1935. Each dot represents 10 acres.
Distribución de yuca en 1935. Cada punto representa 10 acres.

into slices 1-inch thick, sun-dried, and then pounded into a pulp and passed through a sieve. The flour part is used in making bread. Starch is made in much the same way at the individual homes. The tubers are thoroughly washed, scraped, and milled through a corrugated cylinder. The pulp is mixed with water, and the mixture passes over a trough with a sieve bottom. The trough is constantly shaken, and considerable water is poured on the mixture. The part that passes through the sieve is put in containers to settle, the water is poured off, and the residue, or starch, must be washed and rewashed before it is dried as a finished product.

According to the 1935 Puerto Rico Reconstruction Administration census, 6,846 acres were devoted to yuca in 1935, or slightly less than 1 percent of the total land from which crops were harvested. This acreage can be and probably will be greatly increased in the future, as the increasing pressure of population forces more land to be used for subsistence crops. Yuca is a palatable, nutritious, cheap food. It sells for about $1 a hundred pounds. As insect pests are not a limiting factor in the production of this crop, the growers are practically assured of a fair crop, regardless of where or when the crop is planted.

The possibilities of the yuca-starch industry are not so encouraging as is the growing of yuca for home consumption.

BEANS (HABICHUELAS) AND COWPEAS (FRIJOLES)

Beans have been grown in Puerto Rico for many centuries. They are handled in a manner very similar to that used in the United States. The beanfields are small, and in the tobacco districts the beans are planted in furrows after the tobacco has been harvested. On many farms corn and beans are planted in the same field. In many areas beans are planted at any time of the year.

Figure 79, compiled from information from the Puerto Rico Reconstruction Administration census, shows that beans are fairly uniformly distributed throughout the island, although the largest area is in the northwestern part. The municipalities having the largest acreages in beans are Isabela, Utuado, San Sebastián, Orocovis, Cayey, and Morovis. In 1935, 31,470 cuerdas were in beans, or 4.4 percent of the land from which crops were harvested.

The average acre yield is low, but beans are planted on many areas of very shallow soil that are poorly adapted to other crops and not well adapted to beans but which produce a higher profit when in beans than when in other crops. Very often beans on the shallow soils are affected by drought. Beans would be very productive on the well-drained alluvial soils, such as the Toa and Estación, but most of these soils are used for more profitable crops.

Puerto Rico should produce more beans, as it imports yearly about $1,150,000 worth, most of them from the United States. Beans are subject to many insect pests and plant diseases, but generally a fair crop may be expected, regardless of the kind of soil used.

According to the 1935 Puerto Rico Reconstruction Administration census, Puerto Rico has 3,379 cuerdas devoted to cowpeas. Some soybeans, as well as other cover crops, such as jackbeans, swordbeans, crotalaria, and many others, described by Kinman (*25*), are grown.

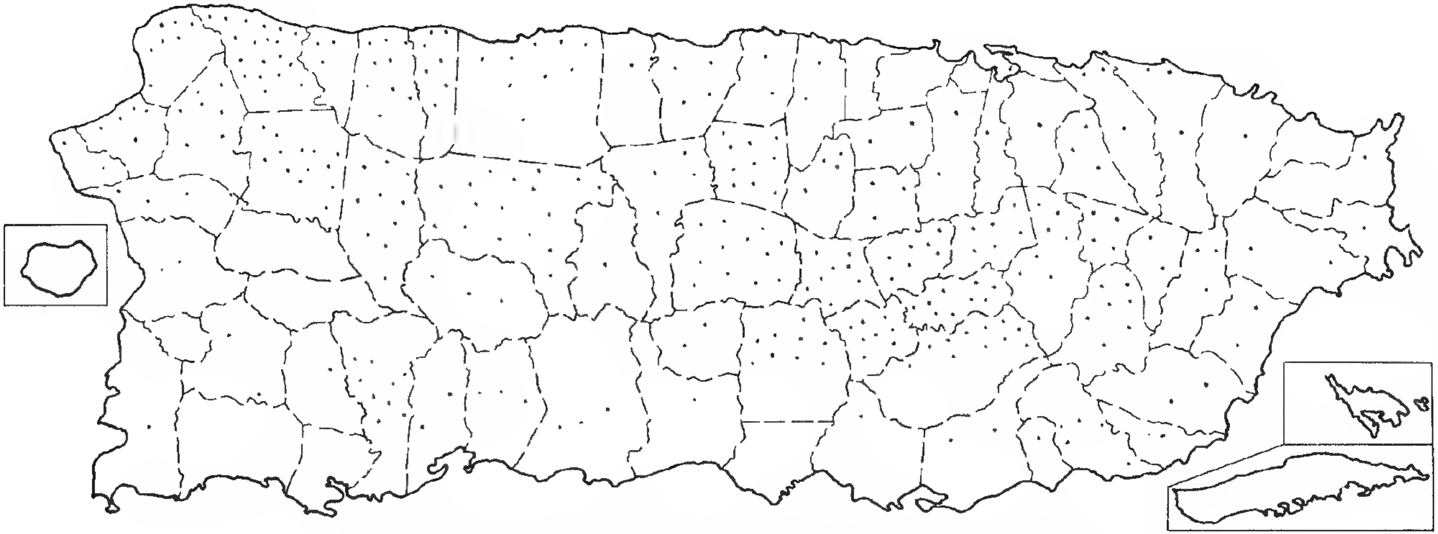

FIGURE 79.—Distribution of beans in 1935. Each dot represents 100 acres.
Distribución de habichuelas en 1935. Cada punto representa 100 acres.

COTTON (ALGODÓN)

Cotton has been grown in Puerto Rico since its early history. The acreage devoted to this crop, however, has varied considerably, owing to the price; during the period 1929–30 the value of exported cotton was about 4.1 cents a pound, and more than 10,000 acres were in this crop each year, but after 1931 the price dropped, the acreage decreased, and the only ginnery on the island suspended operations. Cotton from only 934 cuerdas was harvested in 1935, as reported by the Puerto Rico Reconstruction Administration census.

Cotton is grown only on the sandy soils in the semiarid northwestern part of the island and on the heavy clay soils in the arid and semiarid districts in the southwestern part. Near Isabela cotton is usually planted during January and February, and near Yauco some time in August.

An excellent quality of long-staple cotton is produced. Yields vary according to the soils and the moisture content during the growing season. Yields on Guayabo fine sand seldom exceed 400 pounds of seed cotton to the acre;[21] Guayabo fine sand, shallow phase, produces about 600 pounds; Sabana Seca sandy clay loam, about 800 pounds; Aguadilla loamy sand, about 1,200 pounds; and Fraternidad clay, about 600 pounds.

Land in cotton seldom is irrigated, even in dry years, and only a part of the producers fertilize the crop. The size of the cottonfields ranges from a fraction of an acre to 400 acres. Probably the majority of farms that produce cotton are less than 10 acres in area.

When cotton was a thriving crop, the ginnery furnished seed and fertilizer and advanced money on the crop to those growers who needed assistance.

The future of cotton growing is promising for a limited acreage. This crop can be produced on soils too sandy for other commercial crops, and unless cotton is planted on these soils most of the very sandy areas will be planted to grass. Yields of 1,000 or more pounds of seed cotton can be produced on some of the better soils in the vicinity of Isabela. The production of cotton furnishes work for many laborers, and any such crop or industry should be encouraged as much as possible, in order to relieve the pressing needs of the growing population.

The pink bollworm is a serious pest in the cottonfields, and constant effort will have to be put forth in order to keep destruction from this source to a minimum. The worm has many host plants on the island, which would be nearly impossible to eradicate.

ORANGES (CHINAS)

Oranges have been growing in a semiwild state in the mountains for many centuries, and at present only a few commercial orchards are in existence, although, according to the census of the Puerto Rico Reconstruction Administration, 1,858,284 trees were growing in 1935, of which 1,240,269 were bearing, compared with 663,943 bearing grapefruit trees. The production for the same year was 1,003,988 boxes of oranges and 883,388 boxes of grapefruit.

[21] One hundred pounds of seed cotton is equal to about 27 pounds of lint.

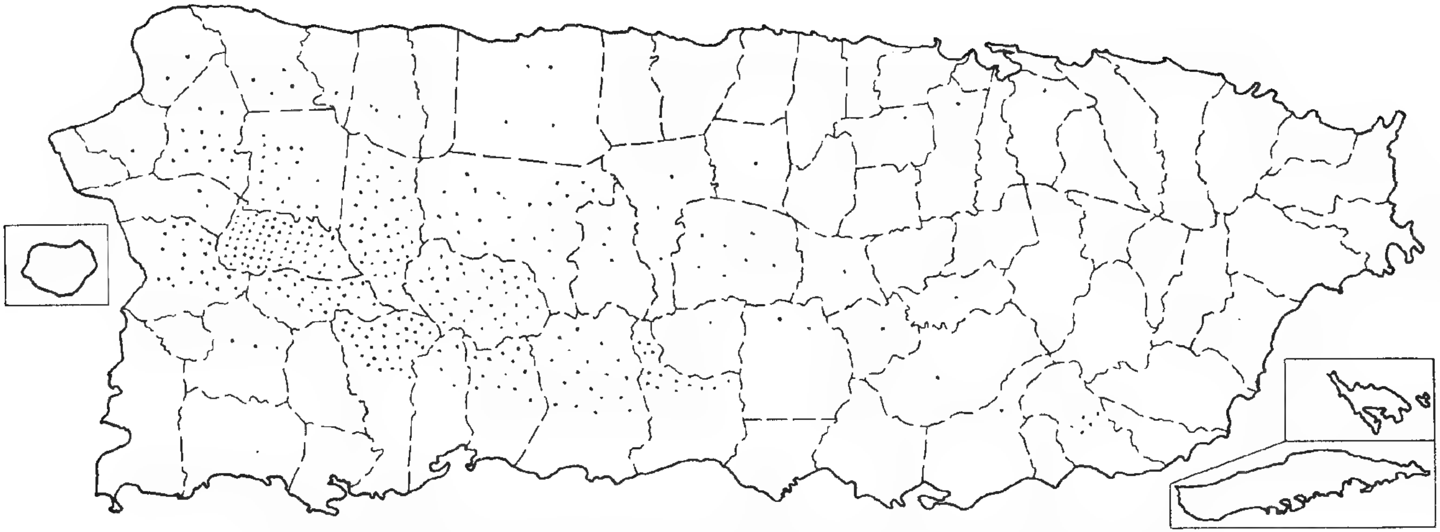

FIGURE 80.—Distribution of orange trees in 1935. Each dot represents 5,000 trees.
Distribución de árboles de naranja (china) en 1935. Cada punto representa 5,000 árboles.

Figure 80 shows the distribution of orange trees as recorded by the 1935 census. It may readily be seen from figures 80, 56, 71, and 72 that the municipalities having the greatest number of orange trees also have a very high number of coffee trees, bananas, and plantains.

In high elevations having a cool, damp climate, orange trees thrive much better than grapefruit trees. Soils well adapted to grapefruit are also well adapted to oranges.

The oranges produced are exceptionally juicy and sweet, and they should have a ready market in the United States. Owing to quarantine regulations, however, shipments during the last few years have fallen from nearly $1,000,000 worth a year between 1917 and 1929 to slightly more than $3,000 worth in 1939, according to the 1938–39 Annual Book on Statistics. The oranges are of much higher quality than the grapefruit grown, that is, compared with similar fruit in the United States.

The season for marketing oranges is from November to May, and during this time oranges may be purchased at nearly any street corner in any town at the rate of two or three for 1 cent. During the summer, when oranges are scarce, the price ranges from 2 to 3 cents apiece. On the farms the price ranges from 15 cents a hundred during the winter to $2 in summer.

In the mountain districts very little attention is given the trees other than gathering the fruit. Very few planters fertilize, spray, or prune the trees. The orange crop is more or less a side issue for the coffee planters.

The future of the production of oranges will depend to some extent on the continuation of the quarantine and the quantity of oranges that can be exported. Many more oranges could be grown than have been in the past, if the growers could realize enough profit to encourage systematic crop management.

Some sour oranges also are produced throughout all the mountain and hill areas. The trees are not numerous and are used only in grafting or budding in the grapefruit groves.

MANGO

According to Barrett (*6, p. 250*), the mango appeared in Puerto Rico about 1740, but very little interest was taken in this tree until 1905, when the United States Department of Agriculture took up the work of introduction in earnest.

The mango is a large, strong, symmetrical, widely branched tree that may grow to a height of more than 50 feet. The trunk withstands hurricanes, even though nearly all the branches may be destroyed. The tree endures many crude prunings by the inhabitants in collecting wood for making charcoal. The mango makes a very attractive ornamental tree for beautifying rural homes.

The fruit, which is more or less oval and weighs from 6 to 9 ounces, is produced during the winter or spring, depending on the elevation and temperature. It is smooth and has a bright-yellow color with some red splotches. The skin is tough and sticks tenaciously to the fibrous juicy flesh. The seeds are large and plump; they are nearly one-half as large as the whole fruit. Some varieties have a very pleasing sweet taste. Practically all the mangoes are eaten raw, but it is possible that in the future some will be canned. The sugar content ranges from about 10 to more than 18 percent.

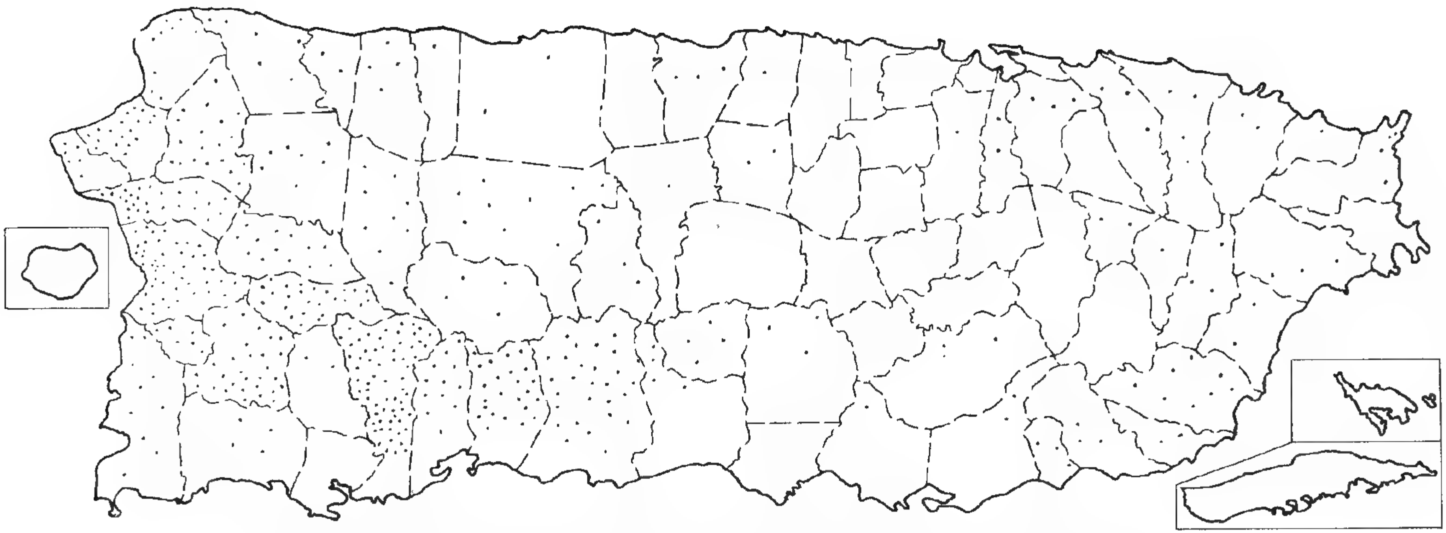

Figure 81.—Distribution of mango trees in 1935. Each dot represents 500 trees.
Distribución de árboles de mango en 1935. Cada punto representa 500 árboles.

Yauco, Mayagüez, San Germán, Ponce, Añasco, and Peñuelas have the largest number of mango trees. Figure 81 shows the distribution of mango trees, according to the 1935 Puerto Rico Reconstruction Administration census.

Although mango trees are distributed throughout the island, the most ideal locations for the production of high yields of good fruit are in areas where the average annual rainfall ranges from 45 to 65 inches. Such areas occur near Rincón, Cabo Rojo, Peñuelas, and other cities.

The fruiting organisms of the mango tree seem to be sensitive to high rainfall, because the production is very low in the humid areas, although the trees are large, plentiful, and have an excellent appearance. The frequency of tropical showers in the humid areas interferes with proper pollination of the flowers. The cold temperature of the higher elevations also may affect production. In very dry areas, most of the trees are not large and do not have a very good appearance. Mango trees seem to grow equally as well on the well-drained deep acid red soils of the interior uplands as they do on the thin brown alkaline soils on steep slopes in the semiarid sections. They do not grow very well on poorly drained or waterlogged soils.

Mangoes are not seriously affected with fungus diseases or by insects, and for these reasons as well as for the fact that they are adapted to almost any soil on the island, the yearly production could be greatly increased. The quality of the fruit produced could be improved to a marked degree through systematic planting and selection of varieties.

AVOCADO (AGUACATE)

The avocado, more correctly called aguacate, sometimes called alligator pear, probably was introduced from Mexico or Central America. Avocados are medium-sized trees having distinctly green-barked rather brittle open branches. The fruit resembles a pear in size and shape, and it has a green leathery skin and yellow soft oily flesh, from one-fourth to one-half inch thick, enclosing a hard seed. The flesh is nearly fiberless and contains from 10 to 30 percent of oil, from 1 to more than 4 percent of fat, and considerable vitamins. It has a very agreeable flavor and is one of the mostly highly prized tropical fruits. It generally is eaten as a salad with salt, vinegar, and dressing.

During August and September, large fresh avocados can be purchased in most of the city markets at 3 or 4 cents apiece. The season lasts from July to November.

Figure 82 shows the distribution of avocado trees according to the 1935 Puerto Rico Reconstruction Administration census. In that year 151,325 bearing trees produced 14,121,900 fruits, or about 100 fruits to the tree.

Avocados grow very well here, and the quality produced is excellent. The number of trees is increasing fairly rapidly, although there are no large commercial orchards.

MISCELLANEOUS CROPS

Some of the other important food crops grown are the papaya or lechoza, breadfruit, rice, potato, peanut, vanilla, lime, and lemon. The papaya may be seen growing in almost any back yard on any soil type. The cylindrical dark-green fruits are borne on short

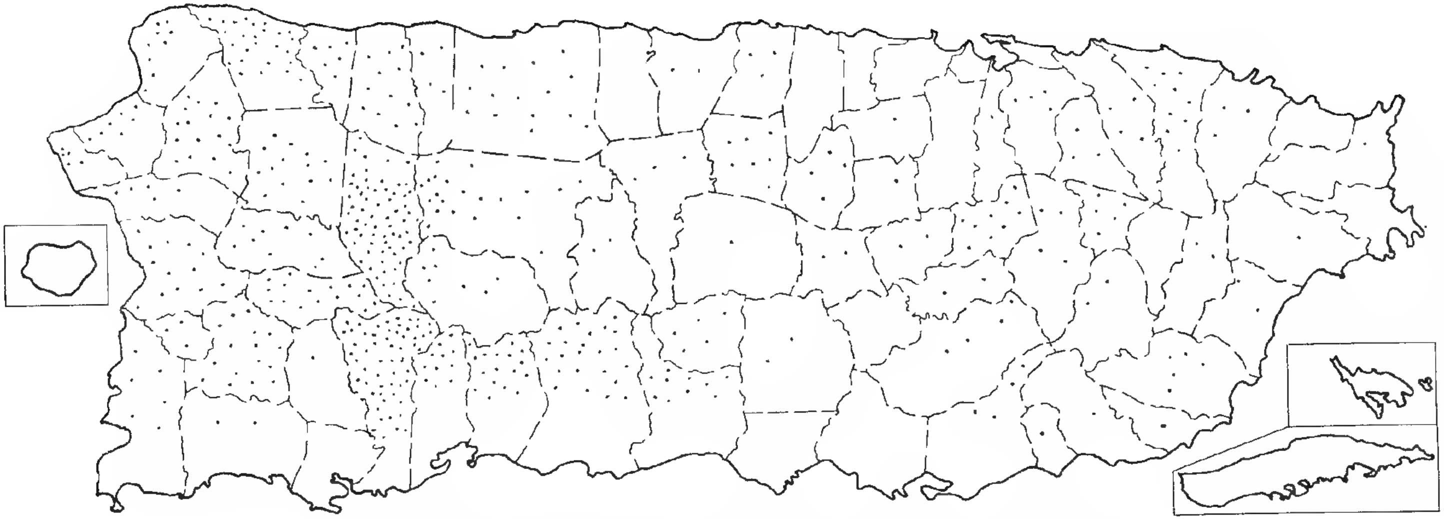

Figure 82.—Distribution of avocados in 1935. Each dot represents 500 trees.
Distribución de aguacates en 1935. Cada punto representa 500 árboles.

peduncles just below the leaves (fig. 83), and they turn yellow when ripe. They have a thin tender skin and yellowish-red pulp. Many of them weigh between 5 and 10 pounds each. The tree may live for several years and produce throughout each year. The male trees are sterile.

Breadfruit is widely grown throughout the island and produces an abundance of large rounded green wholesome fruit, which can be baked, roasted, or boiled, and then fried in thin slices. This fruit is relished by nearly all Puerto Ricans and is produced throughout a large part of each year. The breadfruit tree grows to a height of 25 or 30 feet on most soils. It has striking deeply incised rough leaves and is one of the most generous sources of nutriment that exist in the Tropics.

Upland rice has been grown for a long time. According to the 1935 Puerto Rico Reconstruction Administration census, 9,386 cuerdas were planted to rice in that year. The largest total areas devoted to rice in 1935 were in the municipalities of San Lorenzo, Yabucoa, Corozal, Barranquitas, Morovis, and Orocovis. In the same year, 48,906 bushels were produced.

The 1938–39 Annual Book on Statistics reports that during the fiscal year 1939, 199,331,194 pounds of rice, valued at $5,466,216, was imported; all lowland rice from the United States.

FIGURE 83.—The papaya, or lechoza, has yellowish-red pulp and tastes somewhat like a cantaloup.

La papaya o lechoza tiene una pulpa roja amarillosa y tiene un sabor parecido al del meloncillo (cantaloup).

Rice is planted on the slopes of the Múcara, Cayaguó, and other soils in the spring, and it is harvested during the fall. It yields about 600 pounds to the acre without fertilizer. In places corn and rice are planted in the same field. The corn generally is harvested first. Rice will produce high yields on the alluvial soils or on the coastal plains soils, such as the Espinosa, but the profit derived from this crop is not so large as that derived from sugarcane.

According to the census of the Puerto Rico Reconstruction Administration, 13,683 bushels of potatoes were produced in 1935 from 680 cuerdas. Most of the potatoes are grown in the interior, where the climate is cool and only fairly moist. The leading municipalities in the production of potatoes are Cayey, Cidra, Adjuntas, and Yauco. The potatoes are of fair quality and sell for about 3 cents a pound.

A steadily growing quantity is imported from the United States. During 1939, according to the Annual Book on Statistics, the 48,854,159 pounds imported was valued at $367,350. The jibaros prefer yautia and sweetpotatoes to potatoes, and for that reason a very small acreage is planted to the latter crop.

Only 134 cuerdas were planted to peanuts in 1935. Most of this crop is grown on Aguadilla loamy sand and Aguadilla sandy loam near Aguadilla. The small Spanish variety is preferred. The peanuts are roasted, and many of them are sold in the plaza, a penny's worth at a time, by small children.

Vanilla is a promising crop for the humid and subhumid districts on the well-drained permeable soils fairly high in organic matter. The process of curing the beans has been greatly improved recently, and now a good quality of cured beans can be obtained by skillful growers who understand the proper methods of cultivation and processing. The more energetic growers can make large profits from a small acreage of productive vanilla plants. The Puerto Rico Reconstruction Administration census for 1935 reports the production of 27,911 pounds of vanilla from 69 cuerdas on 33 farms. This enterprise fits in nicely with the growing of coffee. On most coffee farms small acreages of fairly good land that support only a few coffee trees could be used advantageously for vanilla plants. Generally the coffee trees and shade trees are removed, and dwarf búcare trees are set out in rows about 6 feet apart. The vanilla cuttings are set out so that, as the vines grow they will be supported by the dwarf búcares. Within 3 or 4 years the vanilla plants will flower. They must be hand-fertilized—an operation that requires some skill. The pods ripen in the fall and must then be cured carefully. Root diseases are destructive to vanilla plants, and on many farms the plantation must be changed to another part of the farm after a few years of production.

According to the census of the Puerto Rico Reconstruction Administration for 1935 there were 3,860 lime trees not of bearing age and 9,549 trees of bearing age on the island. The largest numbers are in the districts best adapted to coffee, although many limes could be grown on the soils adapted to tobacco or sugarcane. The lime trees receive little or no attention, and the fruit is gathered and sold mainly for local consumption. Generally the price is high and the demand good. The quality of most of the limes is good, but it could be improved through better selection of trees and proper management. The number of lime trees could be greatly increased, and undoubtedly a good export trade could be established with American markets. The production was 8,294 boxes in 1935, which represents a decline of one-half from the production in 1920.

Lemons are of minor importance. The lemon trees are used mainly for grafting purposes on grapefruit farms, and the fruit seldom is seen on the market or used in the homes. Many large goat lemons grow in the mountainous districts, but these are seldom gathered.

According to the Puerto Rico Reconstruction Administration census of 1935, vegetables from 3,616 cuerdas were harvested for sale in that year. The vegetables sold in 1935, ranking according to area, were as follows: Tomatoes, peppers, onions, green beans, pumpkins and squashes, cabbages, eggplants, lettuce, okra, and cucumbers. The municipalities having the largest acreages in vegetables for sale during 1935 were Trujillo Alto, Carolina, and Gurabo. The produc-

tion of vegetables could be greatly increased, if the market justified an increase.

Vegetables grow very well on the Cataño and Aguadilla soils near the coast, and on the Lares soils on the terraces. They also grow well on Múcara soils and the coastal plains soils, such as the Coto, Maleza, Bayamón, and related soils.

A few years ago the production of vegetables was greatly increased in the irrigated district of Isabela, through the aid of the Vegetable Producers Association of Puerto Rico, Inc. This is a farmers' voluntary organization, and during the season of 1931–32, 61 percent of the tomatoes, peppers, cucumbers, string beans, and eggplants shipped from the island were produced in this district. In recent years, owing to low prices, only 8 to 10 percent of the shipments of these vegetables came from this district. Vegetables in this area are produced on soils of the Coto and Maleza series. Yields are very good, and the quality seems to be fairly good.

LIVESTOCK

According to Bagué in El Libro de Puerto Rico (*17, p. 627*) the first introduction of livestock into Puerto Rico was in 1502, when Yáñez, one of Columbus' captains, brought in a few goats and a drove of hogs. About 10 years later, Ponce de León brought from Santo Domingo a few head of cattle and horses, which had been introduced from Spain. In 1534, stallions, descendants from Arabian stock, were brought in from Andalucía, and some years later, other Arabian horses were imported. Undoubtedly, during the early days, some Narragansett pacers from Rhode Island were traded for molasses to some of the owners of sugar mills. Boats from New England took rum, flour, horses, and other products to Africa, where some were traded for slaves. The boats then sailed for the West Indies, where the slaves and the remaining products were sold or traded for molasses to make more rum.

Some of the slave boats were responsible for the introduction during the sixteenth century of the nutritious guinea grass from the West Coast of Africa. This grass and the introduced palatable malojillo grass from South America insured the stockmen abundant nutritious forage throughout the year. The numbers of livestock, especially cattle and horses, increased rapidly under these favorable conditions.

During the middle of the nineteenth century, some of the fine horses from Yabucoa Valley were sold for $1,000 each, and many owners of sugarcane land had fine saddle horses as well as beautiful well-matched driving horses. Most of the horses, however, at that time, were very similar to the ones now on the island, which are small wiry hackney-gaited sure-footed animals used principally for carrying large packs of coffee, bananas, charcoal, and other products down the steep rocky narrow mountain trails and slippery muddy roads to town—to return laden with rice, beans, fish, and other articles of food for the numerous small stores along the trails and roads of the interior. The sugar centrals, ranchers, and others still have fine saddle horses, but they also are small boned. Very few horses are registered.

The distribution of horses is fairly uniform throughout the island (fig. 84). The number has declined since 1910. The number of mules increased from 4,569 in 1910 to 5,827 in 1930 but decreased to 5,081 in

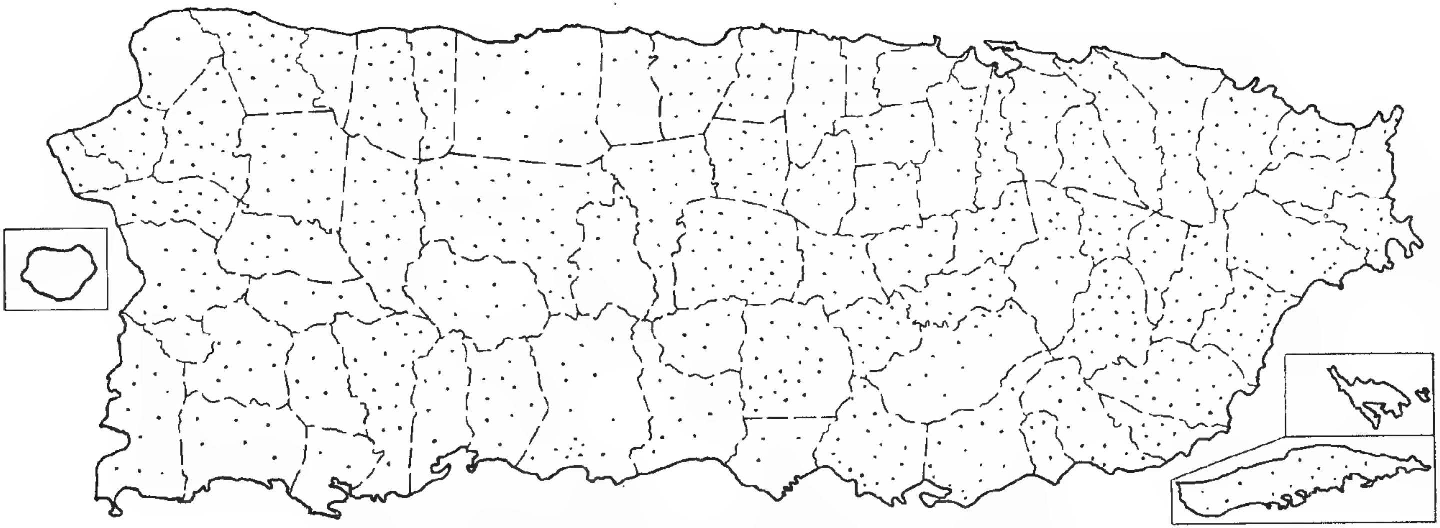

FIGURE 84.—Distribution of horses in 1935. Each dot represents 50 head.
Distribución de caballos en 1935. Cada punto representa 50 cabezas.

1935. Asses and burros are becoming more numerous. There were 2,653 reported in 1935. Only a few of the horses are castrated, owing in part to the danger of infection from the operation and in part to the greater endurance or stamina that stallions have over geldings. Nearly all of the horses are shod, especially those owned by sugar centrals. Very seldom are horses used for draft purposes, but many hundred are seen that have two large wicker baskets, or banastas, securely fastened to a harnesslike saddle, or aparejo, and hanging from both sides of their backs. Many different kinds of packsaddles are in use. Livestock, such as pigs, chickens, and turkeys, as well as all kinds of crops, are transported to market on horseback. Rarely is the western stock saddle seen, as the lightweight English riding saddle is preferred and is better adapted to the small gentle horses. The price of a good young saddle horse ranges from $75 to $125. The cost of pasturing a horse ranges from $1.50 to $2 a month. A few ranchers devote their entire time to the raising of horses, but most of the horses have been raised from colts born on the farms.

Mules are used fairly extensively for draft purposes, especially in the vicinity of Hormigueros, where they haul fertilizer and cane. Considerable areas of ratoon cane are cultivated with one-mule cultivators. Mules are used very extensively in carrying bags of coffee and charcoal from the coffee districts to towns or to highways, where trucks or public cars haul the products to market. Sacks of the coffee and charcoal are tied to the sides of the mules with sling ropes.

Cattle are by far the most important kind of livestock raised. According to the 1930 Federal census, the value of the 310,514 cattle reported, of which 296,235 were on farms, was $10,916,916. Horses, numbering 49,545, of which 42,120 were on farms, ranked second, with a value of $2,380,743. The Puerto Rico Reconstruction Administration census of 1935 reported 42,908 head of horses, of which 35,976 were on farms, and 280,433 head of cattle, of which 266,154 were on farms. The value of livestock is not given in the latter census. The number of cattle has been decreasing since about 1900. Steddom (*38, p. 512*) estimated the number to be 500,000 in 1899.

During the years between 1877 and 1883 and between 1901 and 1905, from 10,400 to 17,297 head of livestock were exported, at a value ranging from $280,932 to $576,577 (*46, p. 54*). Most of them were cattle. Since 1906, very few cattle have been exported, (1) because the island has had increasing demands for cattle, owing to the expansion of the sugarcane industry which required more work oxen (fig. 85) and to the increasing population which needed the beef animals formerly exported; and (2) because the number of cattle produced has been decreasing, partly because hundreds of acres of level fertile land along the arid and semiarid southern coast, formerly in large cattle ranches, have been converted into checkerboard-shaped fields occupied exclusively by sugarcane since 1908, when irrigation projects were developed. Grass still occupies most of the hills along the south coast as well as many of the steep hills throughout the island.

According to the 1935 Puerto Rico Reconstruction Administration census (fig. 86), the distribution of cattle is fairly equal throughout the island. Careful observations, however, show a much larger number along the arid and semiarid southern side and near large cities than in the interior. There are not many cattle in either the coffee or the tobacco districts.

The cattle have been selected for draft purposes for such a long time that they are docile, powerful, large-boned, thick-skinned animals with short hair, wide-spreading horns, and thick polls. Owing to the danger of tetanus following surgical operation, castration generally is performed by bruising the testicle or by rupturing the spermatic cord by torsion without cutting the skin. A pair of good young oxen sells at $75 to $125, and it costs about $1.50 to $1.75 to pasture an animal a month. Practically all of the animals have horns, as dehorning is not practiced. Nearly all of the oxen used on the main roads are shod. They pull heavy two-wheeled carts, plows, and other implements. A team of good oxen can pull from 2 to 3 tons of sugarcane on level, dry, dirt roads. Only one wooden yoke is used for each team. It rests on the polls of the animals and is lashed with a rope or rawhide to the base of the horns (fig. 41). The predominant color of the cattle is buff or light red, although some are black and others

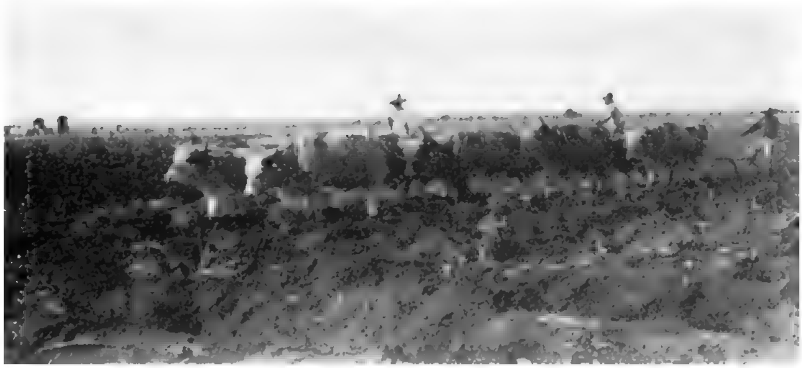

FIGURE 85.—In Puerto Rico, cattle are considered beasts of burden, and they are selected and bred with that object in mind. Small boys ride on the yokes and assist in driving the oxen.

En Puerto Rico se considera al ganado como bestias de carga, y es seleccionado y críado como tal. Muchachos se montan sobre el yugo y ayudan a llevar los bueyes.

are dark red. There are very few roans or spotted animals. Of the cattle on farms in 1935, 72,029 were work oxen.

The Brahman or zebu cattle, which have been imported to a considerable extent from Texas within the last 15 years, are white or fawn-colored. They are faster walkers, stronger, and some farmers say that they are more resistant to tick fever than the so-called native cattle. Cows with from one-third to two-thirds zebu blood are said to give more milk than the native cows, and their calves are fatter and stronger than those from the native cows. These cattle, however, are more vicious and are hard to break in to work, also more difficult to keep in a pasture than are other cattle.

Most of the cattle ranches have some zebu (fig. 87) and some native stock. A one-third zebu and two-thirds native cross is recommended for draft purposes by many of the more progressive ranchers. The ranches along the arid southern coast are very similar to the ranches in Arizona, New Mexico, and some other Western States. All the land is fenced, however, as there is no free range. Some ranches

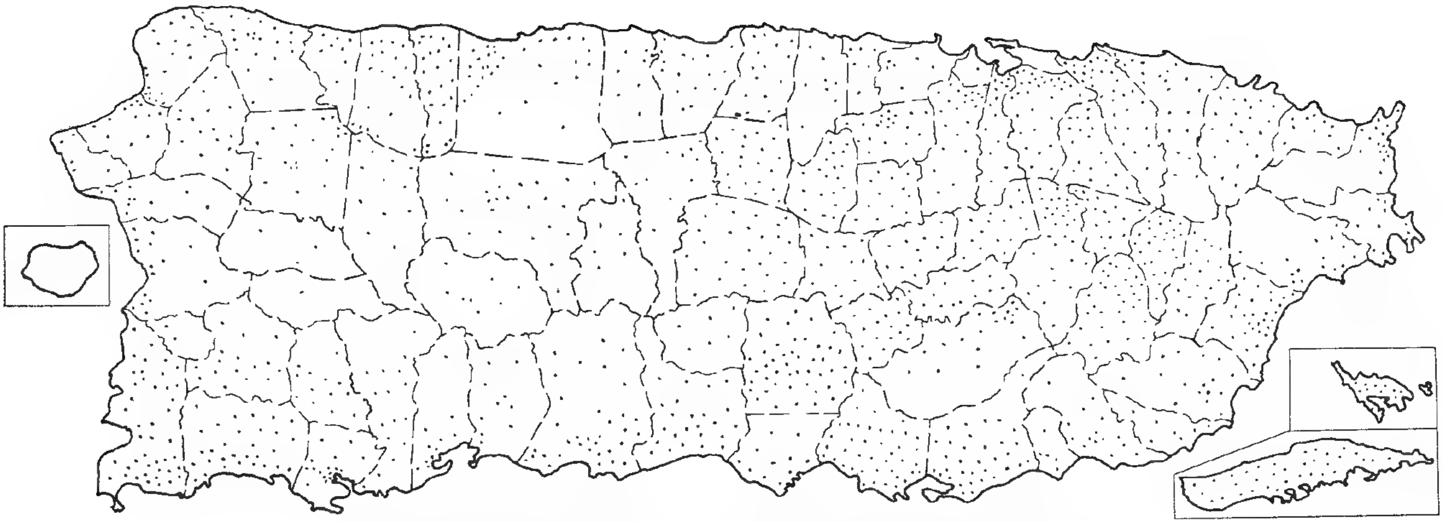

FIGURE 86.—Distribution of cattle in 1935. Each dot represents 200 head.
Distribución de ganado vacuno en 1935. Cada punto representa 200 cabezas.

support from 1,000 to 2,000 cattle on from 3,000 to 4,000 acres of pasture land that is fenced and cross fenced with three and four strands of barbwire. Posts from the native búcar, mabí, and jácana trees are set 6 or 9 feet apart. Regardless of the soil type, the posts rot a few inches below the surface within a period ranging from 5 to 10 years, depending on the kind of tree used. The búcar posts last about one-half as long as the mabí. Throughout the range land the large tamarindo and algarrobo trees are very conspicuous, with the livestock resting under their many spreading branches.

The common practice is to put about 50 cattle in a 50- or 60-acre pasture for several days, then change them to another pasture. The yearly carrying capacity of the land ranges from 2 acres a head on the level Fraternidad and Paso Seco soils to 4 or 5 acres a head on

FIGURE 87.—A herd of livestock on a cattle ranch north of Central Aguirre. Many of the animals have some zebu blood.

Ganado en un rancho al norte de la Central Aguirre. Muchos de los animales tienen sangre zebú.

the Aguilita, Ensenada, and Descalabrado soils. The capacity also varies considerably from year to year and from place to place, depending on the rainfall, the care of the pasture, and the kind of grass. An increased annual rainfall of 20 inches will nearly double the carrying capacity in districts receiving an average ranging from 30 to 40 inches. Pastures that have been freed of cacti, brush, zarzarilla (fig. 88), and guayacán blanco, or guayacanillo, have a higher carrying capacity than neglected fields. Zarzarilla spreads rapidly, and the animals that eat it seem to lose some of their hair and manes. The cost of destroying this weedlike bush, which grows in the arid and semiarid districts, is about $2.50 an acre. Guayacán blanco, or guayacanillo, grows on the shallow soils derived from limestone, in both the arid and humid districts. The pollen from this plant seems to irritate the eyes of the animals, and some ranchers have reported that it causes blindness in cattle.

The carrying capacity of the pasture land depends to some extent on the manner in which the livestock are handled. Cattle that are badly infested with ticks require a larger area over which to graze in

order to be in as good condition as are the nearly tick-free cattle. Ticks are a serious pest in all parts of the island, and a tick-eradication program is being initiated. Tick fever is sometimes fatal to imported dairy cattle. Most of the so-called native cattle and the zebu strains are more or less immune to tick fever, but the ticks do much harm to the animals by sapping their strength, which is of vital importance during the long dry periods when the pastures are overgrazed. In places along the southern coast, many hundreds of cattle die of starvation during a long dry season, such as that during the winter of 1930–31. Generally speaking, the first to die are those most heavily infested with ticks.

Tuberculosis among cattle also is prevalent but is not so serious as might be expected. A systematic tuberculosis testing and eradica-

FIGURE 88.—A badly infested guinea-grass pasture near Faro Cabo Rojo. Most of the brush is zarzarilla.

Yerba de guinea infestada, cerca del Faro de Cabo Rojo. La mayor parte de la maleza es zarzarilla.

tion program has been in progress for the last few years, under the direction of the United States Department of Agriculture, and it is hoped that all the range cattle, oxen, and dairy cattle on the island will soon be free of tuberculosis.

Most of the pasture in the arid districts has been planted with guinea grass, which grows from 2 to 8 feet high and seems to be much more nutritious than grass grown in the humid sections. Cattle raised in the arid districts are generally in better condition, have better health, and look better than animals born and raised on acid soils of the humid districts, where the grass is coarse and dense but less nutritious. Another important grass in the arid districts is Bermuda grass, which is resistant to alkali and salt. It is grown to a large extent on level lands near the coast that are subject to alkali. Bermuda grass is relished by the cattle much as it is in the United States. It and horquetilla (fig. 14), a fine-leaved slender grass, propagate naturally over the arid and semiarid districts. Horquetilla is fairly nutritious, but good stands of it very often are plowed under,

and guinea grass is planted. Bunches of guinea grass generally are planted in rows, often interplanted with corn, during the rainy season, and in some places the seed is planted. The seeds, however, may lie dormant in the soil for some time before they receive enough moisture for germination. After the guinea grass becomes large it will spread in the better soils, such as the Fraternidad, Paso Seco, and Yauco, but in the Aguilita, Ensenada, and similar soils, guinea grass grows only in the rows in which it was planted from 5 to 10 years ago. The guinea grass may become brown and dry during long droughts, but cattle will exist on the dead-appearing stems. Within a very few days after a rain, the grass in the previously brown baked pastures will become green and fresh. In some of the best

FIGURE 89.—Drawing water with oxen from an open dug well about 30 feet deep. The water is brought to the surface in a barrel, after which it is conveyed to a concrete trough.

Sacando agua de un pozo de 30 pies de profundidad. El agua es sacada a la superficie en un barril, después se echa en una canal de concreto.

pastures the cattle may be completely hidden by the tall dense guinea grass.

Water for livestock in the arid districts is drawn from dug wells (fig. 89) by hand and by windmill pumps. In many places the water is brackish, and additional salt for the animals is not necessary and is rarely seen near the corrals or in the pastures.

The grasses planted in the interior of the island for livestock are molasses grass, a prostrate twining fine hairy sweet-odored grass that is relished fairly well by livestock after they become accustomed to it; Guatemala grass, a rank-growing nutritious grass well adapted to acid soil in humid sections; and Napier grass (elephant grass), which resembles Japanese sugarcane in some respects. All the molasses grass is pastured, and after it becomes established it is an excellent grass for the prevention of soil erosion. It would be exceedingly difficult for water passing across a field of this grass to have sufficient force to wash soil particles from the intricately woven lower leaves and roots. The Guatemala and Napier grasses generally are cut by hand, made into bundles, and carried to the stables or corrals. In

this way enough hay can be gathered from an acre of most soil types to feed four or five oxen or dairy cows throughout the year. Other grasses of importance for livestock in the humid districts are grama or St. Augustine grass, cerrillo, and matojo. The so-called grama is superior to the other two and is an exceedingly good grass when grown on the alkaline soils, such as the Colinas, Soller, and Santa Clara. This grass also is good for the control of erosion, as its long runners securely anchor themselves to the soil and extend over gullies and on both sides of ditch banks, thus binding the soil in place. Cerrillo grows mostly in the subhumid districts, but it grows to some extent in the humid areas. It is considered a good grass for cattle or horses. Matojo grows in humid areas or on poorly drained soils. It is a rank-growing coarse grass of doubtful value for livestock. Although the animals eat it, it does not seem to keep them in good condition. It is also used in thatching houses, especially the roofs. Malojillo grass (fig. 90) probably is the most satisfactory grass on the island. It is a tall coarse grass that is always green. It is very palatable and an exceedingly heavy producer. Yields ranging between 7 and 8 tons to the acre are the average, and some fields have been said to produce 40 tons an acre during 1 year. This grass grows only on poorly drained soils or in humid districts. It would grow in the arid districts if the land were irrigated.

Most of the dairies are concentrated near the large cities, although many very large combination dairy and livestock ranches are in the arid districts. On some ranches from 100 to 200 cows are milked. The range cows are milked once a day and also suckle their calves. These cows give about 2 quarts of milk a day, and the strictly dairy cows give about 17 quarts a day. Many of the regular dairies have very good dairy cows and up-to-date equipment, but some dairies are neither efficiently run nor very sanitary. Milk costs from 12 to 20 cents a quart in the cities. The cost of feeding the dairy cows is very high, as most of the grain feed is imported from the United States. Malojillo grass is one of the main forage feeds, and it also is expensive. Nearly all of the main dairy breeds are represented on the island.

The number of sheep has declined rapidly since 1910. At that time, according to the Puerto Rico Reconstruction Administration census, 5,525 sheep were reported, but in 1930 only 3,259 were reported; and in 1935, 3,363. The constant hot weather does not favor the production of wool or a good quality of mutton. The largest numbers of sheep graze on the steep hills of the arid southern coast. The sheep are small, thin, straggly, and neglected. They roam about the pastures in small flocks and are restrained only when they attempt to enter a field of sugarcane.

The number of goats has decreased from 49,079 in 1910 to 36,478 in 1935. This is about the same as the number of goats in Utah in 1935. The climate and environment are well adapted to goats, and the number of these animals should be increasing instead of decreasing, as there are many hundreds of acres that are better adapted to the raising of goats than to anything else. Such soils as the Tanamá, Aguilita, San Germán, and many others could provide pasture for many thousands of goats. An increase in the number of goats would

FIGURE 90.—Rank-growing malojillo grass on Coloso clay in the eastern part of Puerto Rico. The hills in the distance are very similar to the hills in the prairie regions of continental United States.

Malojillo en Coloso arcilloso en la parte este de la isla. Las colinas a lo lejos son muy similares a las de las praderas de los Estados Unidos continentales.

give an additional needed milk and meat diet to the jibaros and their families. Goat and kid meat are relished by all classes of Puerto Ricans. Many kinds and colors of goats run loose about the island—from the city streets to the mountainsides. Most of them are in fairly good condition (fig. 91) and very active. It is unusual to see more than five in a flock, as most of the animals are owned by the jibaros who sell a part of their flock when they have more than two or three.

Hogs are fairly well distributed throughout the island (fig. 92). The number of hogs decreased from 103,041 in 1910 to 69,266 in 1930, and then increased to 79,508 in 1935. The last census shows that there are more hogs on the island than in any New England State except Massachusetts. In 1930 only 818 were registered. Most of them are of mixed breeding, and constant inbreeding has had its ill effects. The hogs are similar to the Tamworth bacon type, as they

FIGURE 91.—Goats cropping the grass in the range land of Puerto Rico. The mean annual rainfall in this vicinity is about 40 inches.

Chivos pastando. El promedio anual de lluvia en esta vecindad es de 40 pulgadas.

are long, rangy, and thin with very little good fat meat. Most of them are red, but it is not unusual to see any ordinary color or combination of colors. Only a few hog ranches were noticed during the course of the survey. Generally the farmers have only one or two hogs each. The hogs may be confined to a pen but commonly are picketed to a small tree somewhere about the farm. Most of the hogs are marketed by leading them to town, but some are hauled on the bumpers of the public cars that carry both passengers and produce to and from town.

The hogs forage for themselves, living on roots, fruits, and nuts. Very few farmers feed much corn, and practically no mash or milk. Fortunately there are many nutritious nuts, such as the seeds of the royal palm and of the poma rosa, or rose apple, that are fairly abundant throughout the island.

According to the 1938–39 Annual Book on Statistics, $2,719,524 worth of pork and sausage and $2,373,103 worth of lard were imported from the United States during that fiscal year. This would indicate that a better quality of lard-producing hog should be raised.

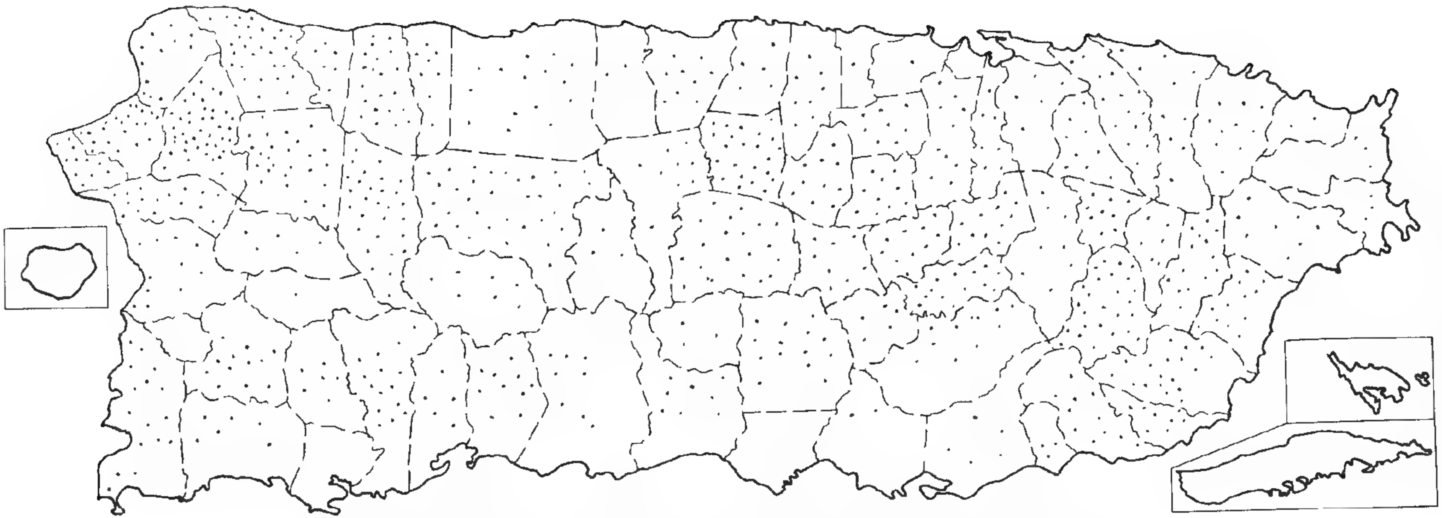

FIGURE 92.—Distribution of hogs in 1935. Each dot represents 100 head.
Distribucion de cerdos en 1935. Cada punto representa 100 cabezas.

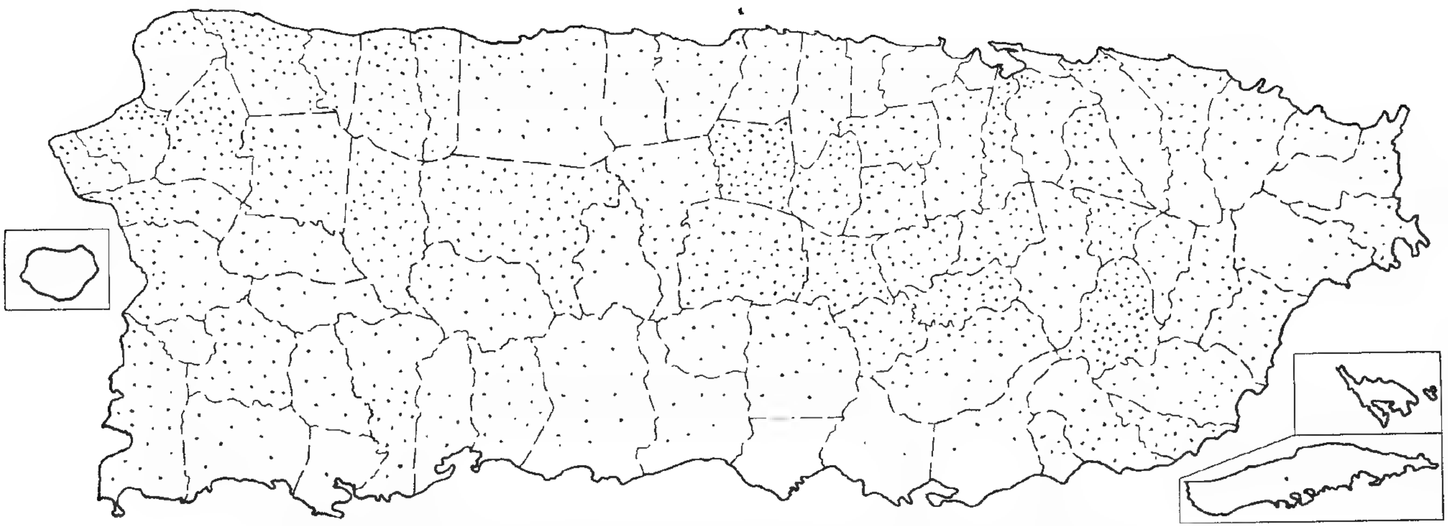

FIGURE 93.—Distribution of chickens in 1935. Each dot represents 500 chickens.
Distribución de aves (gallinas) en 1935. Cada punto representa 500 aves.

If as much advancement had been made in the production of corn as has been made in the production of sugarcane during the last 20 years, the hogs, corn, and, in fact, the island as a whole would be much better off today.

Nearly every rural family has a few chickens, but the average for 1930 was less than four chickens to a family. The distribution throughout the island corresponds fairly closely with the distribution of the rural population as can be seen by comparing figures 93 and 21. According to the 1935 census of the Puerto Rico Reconstruction Administration, the number of chickens on the island increased from 599,070 in 1910 to 684,448 in 1930 and decreased slightly to 667,749 in 1935.

Most of the chickens are a mixture of many breeds, but strains of the fighting cock or game bird probably are dominant, especially in many of the remote rural districts. They are good foragers and are active but are small and lean. They lay very small brown eggs that sell for about 15 cents a dozen less than eggs from the large breeds, such as the Plymouth Rock and Rhode Island Red. The Leghorn, Plymouth Rock, Rhode Island Red, and Minorca breeds seem to thrive, although undoubtedly they are less resistant to some diseases than the so-called Spanish chickens. Much improvement can be made in the poultry, both in regard to egg laying and meat production. The game birds receive more attention than any other livestock on the farm. They are exceedingly well groomed, fed, and trained. Cock fighting is legalized, and it receives more interest than any other form of amusement. Good fighting cocks sell at very high prices. Generally they are kept near the house, with one end of a string tied to a leg and the other end to a tree, stick, or rock.

Chickens do much better on well-drained soils having good circulation of air than on poorly drained soils. Many areas of very sandy soil, very rocky land, and soil low in fertility, that are not adapted to crops, make very desirable land for the raising of chickens. The Nipe, Corozo, and Aguilita soils, as well as the stony areas of many other soils, could be used advantageously for poultry yards. The island imports both poultry and eggs. During the fiscal year 1939, the United States sent to Puerto Rico 340,189 dozen eggs valued at $85,801, according to the 1938–39 Annual Book on Statistics.

Turkeys and guinea fowls are raised throughout the island. The largest numbers of turkeys are raised in the arid districts where diseases are not so prevalent. Guineas do well in nearly all districts and when killed and cooked are a favorite holiday food among the natives.

SOIL-SURVEY METHODS AND DEFINITIONS

The method used in making the detailed soil map of Puerto Rico was to traverse nearly all of the area in a car or on foot at intervals of one-fourth mile or less. The regular plane-table (fig. 94) survey method (*24, p. 37*) was used during the first two and the last winters. In 1931, the United States Navy took aerial photographs of approximately one-half of the area. These pictures were on a scale of about 1:10,000 and were used advantageously in the soil survey. Some of the aerial pictures were made into mosaics and reduced to a scale of about 1:40,000, and these were used in the field by covering them with thin pyralin paper, on which the soil boundaries, roads, and other features

were drawn. The method most generally used was one in which pyralin- or kodaloid-covered contact prints (fig. 95) were taken in the field, and on them was shown the location of the soil boundaries, streams, houses, and other features. Later the pyralins and koda-

FIGURE 94.—Soil surveyors making a detailed soil map by the regular plane-table survey method.

Técnicos de suelos haciendo un mapa detallado de suelos por el método de la plancheta.

loids were compiled, traced, reduced, and adjusted to a plane-table traverse of the main roads.

The soil was examined in many places to depths ranging from 3 to 6 feet, with a spade and an auger, in order to observe the variations of

FIGURE 95.—See legend on page 169 and table 12 on page 171.

the physical and some of the chemical properties of the surface soil, subsoil, and substratum. The surface soil and subsoil are referred to as the solum, and the substratum, in most instances, as the parent material. Collectively these terms include the soil profile. Like soils are combined into soil types, and their areas are delineated on a 1-inch to a kilometer scale map.[22] Careful attention has been given to the yields of crops growing on the different soil types and to the agricultural practices under which the yields were obtained.

The general features noticed in the examination of a soil are topographic position, drainage, parent material, native vegetation, apparent productivity, erosion, and crops produced. Careful observations are made of the color, texture (size of the individual soil grains), structure (arrangement of the soil grains into soil aggregates), and consistence (compaction, plasticity, or friability of the soil grains and soil aggregates) of the several layers of soil. The content of organic matter, roots, cracks, depth to lime, pH value, and other characteristics also are noted.

The different kinds of soil are grouped into series and types. The series is the broader group and may include one or more types. A soil series is a group of soil types that have certain physical and chemical properties in common. Some of the physical properties noted are the arrangement and thickness of the soil layers, or horizons, from the surface downward and color, consistence, and structure of the soil material; and some of the chemical properties noted are the relative amounts of organic matter, lime, and iron compounds present and the degree of acidity or alkalinity. The soil type, a subdivision of the series, is separated on the basis of texture of the surface soil. The series is given a geographic name, such as the name of the municipality or barrio where the soil was first mapped [23] and described, and this name, together with the name of the texture class, constitutes the name of the soil type. For example, a soil near Río Piedras, occurring on undulating or rolling uplands, having a yellowish-brown or reddish-brown acid surface soil and a plastic medium-compact mottled red, gray, and brown acid subsoil overlying fragmental shale, at a depth ranging from 26 to 36 inches, is classified in a series called

FIGURE 95.—Aerial photograph of about 400 acres of coastal plains in the vicinity of Vega Alta. In the field the soil-type boundary lines are shown on transparent pyralin or kodaloid paper that is fastened to the prints. The field data are transferred later to a plane-table traverse control map on a much smaller scale. This picture shows the density of rural dwellings, the large number of soil types, and from table 12 a correlation can be seen between soil types, land use, and plant growth. (Photograph taken by U. S. Navy.)

Fotografía aérea de alrededor de 400 acres de llanos de la costa en la vecindad de Vega Alta. En el campo los límites de los tipos de suelo son marcados en pyralina transparente o papel kodaloid que se coloca sobre la fotografía. Estos datos de campo después son transferidos a un mapa de control a una escala mucho menor. La fotografía muestra la densidad de las viviendas rurales, el gran número de tipos de suelo, y en la tabla 12 se puede ver una correlación entre los tipos de suelo y cosechas adaptables. (Fotografí tomada por la Marina de los EE. UU.)

[22] The published map is on a scale of 2 centimeters to a kilometer, or 1 : 50,000.

[23] Most of the soil series names occurring in this report and on the accompanying soil map are from geographic names in Puerto Rico, as these soils were mapped for the first time on the island. A few names have been introduced from the Virgin Islands, Cuba, and the United States.

Río Piedras, and if the surface soil is clay the type name is Río Piedras clay.

Río Piedras soils occur only on the uplands. Soils subject to frequent overflows, like the Toa and Coloso, occur only on bottoms, and soils of the terraces, like the Vía, occupy terrace positions only. Slight variations from the typical soil, in such features as relief, shallowness, or stoniness, frequently are described as phases. For example, an area of a soil type that has unusually steep relief may be designated as a steep phase of the typical soil.

The finer parts of all soils are composed of particles of different textural sizes, and these particles are grouped, according to size, under three principal heads, namely, sand, silt, and clay. The sand particles are the largest and are readily seen by the naked eye. The particles are rough, hard, gritty, and generally are noncoherent. Silt particles are microscopic in size and when wet are velvety to the touch, lacking the roughness of sand or the stickiness of clay. Clay particles are the smallest; some are so small that it is impossible to see them with a powerful microscope. Most of the clay particles when wet are plastic and sticky and when dried become hard and brittle. Different soils have different proportions of sand, silt, and clay, but generally every soil has some of each.

Soils have different characteristics, in part owing to the different proportions of sand, silt, and clay. Sand soils in general are comparatively unproductive and droughty, and their loose, open character causes them to drift readily when they are cultivated and unprotected by vegetation. The sandy loam soils contain more silt and clay than the sand soils and are, therefore, more fertile and have greater water-holding capacity. The loams are spoken of by many as the "all-round" soils and are, as a rule, adapted to a greater variety of crops than soils of other classes. Many of the sandy clay soils become very hard when dried, after having been wet a long time, as the clay particles have a cementing effect on the sand grains. The silt loam and clay loam soils are heavier in texture than the loams and require more careful management, in order to maintain good tilth, but for the most part they are strong soils and are suitable for many crops. The silty clay and clay soils contain more than 40 percent of clay, and many of them are very hard to work when wet, as the particles run together, and on drying, large hard clods are formed. At proper moisture conditions they can be handled easily, and they then form a good seedbed. Many clay soils absorb water very slowly and retain it a long time, as they have a large water-holding capacity, but some soils in Puerto Rico, containing more than 50 percent of clay, are friable, permeable, and do not retain moisture any better than sandy loams. Such soils have physical characteristics more like those of a loam than of a clay and are of common occurrence in the warm, moist Tropics. They have a high content of iron and alumina and a low content of silica. They are often spoken of as lateritic clays, and they have a lower capacity for the absorption of bases and retention of plant nutrients than do most other clays.

On the soil map that accompanies this report the areas occupied by the different soils are delineated according to soil types and phases. Each soil type and phase is shown by a separate symbol that corresponds to the soil legend. Table 12 gives a descriptive legend of a few soils that occur along the north coast. Land that is impregnated with

harmful quantities of salt is indicated on the map by a red boundary line. The concentrations of salt at specific locations are indicated on a percentage basis and are shown on the map.

TABLE 12.—*Descriptive legend for figure 95, showing correlation between soil types, land use, and plant growth in Puerto Rico*

Symbol	Soil type	Character of soil and principal land use
Ac	Almirante clay	Heavy brownish-yellow soil, poor for nearly all crops.
An	Almirante sandy clay	Do.
Bc	Bayamón clay	Deep red heavy-textured soil, fair for all crops.
Bs	Bayamón sandy clay	Deep red heavy-textured soil, fair for all crops, very similar to Bayamón clay.
By	Bayamón sandy clay loam	Deep red rather heavy textured soil, fair for sugarcane and pineapples.
Bf	Bayamón fine sandy loam	Deep sandy soil, good for citrus and truck crops.
Cz	Corozo fine sand	White coarse sand, very poor soil for all crops.
Ey	Espinosa sandy clay	Yellowish-red fairly heavy soil, only fair for most crops.
Eo	Espinosa loamy sand	Yellowish-red sandy soil, good for citrus and truck crops.
Sx	Santa Clara clay	Black heavy plastic medium deep soil, good for sugarcane.
Sk	Soller clay loam, hilly phase	Black heavy plastic shallow soil, excellent for grass.
Su	St. Lucie fine sand	Deep white coarse sand, very poor soil for all crops.
Ta	Tanamá stony clay	Shallow soil used only for brush.
Vf	Vega Alta fine sandy loam	Reddish-brown sandy soil, excellent for citrus crops.
Vl	Vega Alta loamy fine sand	Do.

The areas of the different soil types are outlined, although the distinction between any two adjoining soils is not everywhere sharply defined. In a few places, the soil boundaries do represent sharp changes, but in most places they indicate a transitional area between the two soil types. In many places the exact position of the boundary is an expression of the judgment of the man making the soil survey. The decisions of different fieldmen on any one unit or small tract may differ considerably, but in examining large areas, the results will be similar in most places. The soil maps should not be depended on entirely, without further field inspection, for the purchase or sale of individual farm units, but they should prove very useful as a guide for the purchase of land, establishment of fertilizer experiments, estimates of crop yields that may be expected from the soil types, and similar information.

SOILS AND CROPS

Many of the world's great soil groups are represented in Puerto Rico by some of the 115 soil series (including 352 soil types and phases) or one of the 6 miscellaneous land types. This is an unusually large number of soils for an area smaller than some of the western counties in continental United States. The factors responsible for soil development—climate, native vegetation, relief, age, and parent material—are extremely varied within short distances in Puerto Rico, and therefore a large number of soil types may be expected.

The average annual rainfall ranges from less than 30 inches in the southwestern part of the island to more than 200 inches in Sierra de Luquillo. The native vegetation ranges from the desert shrub type to the typical rain-forest type. The elevation ranges from sea level to 4,398 feet above on Cerro de Punta, south of Jayuya. The relief varies from level to precipitous. The age of the soils ranges from that of the recent alluvial deposits along streams and young soils on steep slopes to that of the very old soils developed on nearly flat remnants of ancient plateaus. The parent material has been produced, through the processes of weathering, from many different kinds of rock, such

FIGURE 96.—See legend on page 173.

as Tertiary limestone, Cretaceous limestone, shales, tuff, volcanic ash, igneous intrusions, such as granites and andesites, and metamorphic rocks, such as serpentine, sandstone, and many mixtures of volcanic rock. These different rocks occur within different rainfall belts and many slope gradients, thereby greatly increasing the number of mappable soil types.

Some of the soils are similar to some of the soils in southern United States, but much larger numbers are similar to soils in more tropical countries, as Cuba, Santo Domingo, and the Virgin Islands.

As a discussion of the relationships between all the crops grown in Puerto Rico and all the soil types would be too lengthy, only the more important commercial crops will be discussed. The main crops are sugarcane, tobacco, grapefruit, bananas, pineapples, beans, sweetpotatoes, hay, corn, coffee, oranges, coconuts, yautia, plantains, yuca, pigeonpeas, ñames, and cotton.

If Puerto Rico were viewed from the air at a high altitude, one could distinguish readily several outstanding land forms that more or less encircle the island in ribbonlike bands, and each produces specific commercial crops (fig. 96). Beginning at any point along the coast and proceeding toward the interior, the most conspicuous correlation is that between the large coconut groves and small truck farms with the sandy coastal lowlands; the mangroves and salt-resistant vegetation with the swampy coastal lowlands; the level checkerboard-shaped fields of green succulent sugarcane with the nearly level river flood plains, terraces, and alluvial fans; a variety of crops with the smooth coastal plains; sugarcane with the undulating or rolling inner plains; and pineapples, tobacco, subsistence crops, coffee, bananas, oranges, forest trees, and grass with the rather restricted districts on the steep uplands.

If these several physiographic divisions or land forms are thoroughly studied, a definite cause will be discovered for the fact that farmers plant specific crops on certain types of land. In most places the determining factors for land use are climate, soil characteristics, relief, elevation, economic conditions, or a combination of these factors.

FIGURE 96.—Aerial view along Río Mameyes, showing ribbonlike bands of soil and the close correlation in land use. (The letter symbols are those used on the soil map to denote the various soils.) Palm Beach sand generally is barren or supports some xerophytic vegetation. Cataño sand generally is planted to coconuts intercropped with sweetpotatoes, yuca, and other subsistence crops. Nearly all of Saladar muck is covered with mangroves. Palmas Altas silty clay loam and clay are mostly in malojillo grass. The Coloso, Estación, and Mabí soils in general are occupied by sugarcane. Most of the Múcara and Juncos soils are in pasture and subsistence crops; many of the better areas near the road are in sugarcane. (Photograph taken by U. S. Navy.)

Vista aérea a lo largo del Río Mameyes, mostrando bandas de suelo en forma de cintas y la estrecha correlación en el uso de la tierra. La arena de playa generalmente es estéril con alguna vegetación xerofítica. La arena Cataño generalmente se siembra de cocos intercalados con batatas, yuca y otros cultivos de subsistencia. Casi todo el Saladar muck está cubierto de mangles. El Palmas Altas limo-arcilloso lómico y Palmas Altas arcilloso principalmente se siembran de malojillo. Los suelos Coloso, Estación, y Mabí se siembran casi exclusivamente de caña de azúcar. La mayor parte de los Múcara y Juncos están en pasto y en frutos menores; las mejores áreas cerca de la carretera a menudo están en caña. (Fotografía tomada por la Marina de los EE. UU.)

Most of the well-drained soils of the coastal lowlands, which form a discontinuous narrow strip fringing the coast, are nearly level, loose, sandy, and alkaline. These soils are preferred for coconuts and minor crops, such as sweetpotatoes, yuca, peanuts, and melons, because these crops are more profitably grown on the sandy soils than they are on the heavy clay soils or the poorly drained soils. Then, too, coconuts grow better and produce higher yields near the sea at low elevations than they do inland on high elevations. These sandy soils are too loose for profitable yields of sugarcane, too near the sea for good-quality tobacco, too low and too dry for coffee, and in general too alkaline for pineapples. Guinea grass and citrus trees would grow very well. Because these soils are so sandy and droughty, the principal native vegetation is xerophytic in character, regardless of whether the soil occurs in the humid or in the arid sections.

The poorly drained lands of the coastal lowlands include both organic and mineral soils. They occur adjacent to and inland from the beach or coast line. They have flat relief and are composed of soil having a high content of plastic sticky clay, muck, or fibrous peat. The elevation of these soils ranges from sea level to 2 feet above. Adequate drainage involves an expensive establishment of ditches, dikes, and pumps. The undrained organic soils in both the arid and humid sections are acid and salty, and they produce mangroves and other halophytic vegetation. The principal enterprise in these swamp areas is the making of charcoal from the native mangrove thickets that grow rapidly and readily, regardless of the salt content of the soils. The organic soils that have been adequately drained produce fair yields of sugarcane, but the content of sucrose in it is very low. Most of the mineral soils of the poorly drained coastal lowlands are adjacent to or closely associated with the organic soils. They are acid in the humid sections and calcareous in the arid sections. In the humid sections they produce fair malojillo grass, and when drained they make fair or good soils for the production of sugarcane. Most other crops, with the exception of rice, would be a failure on such land. In the arid sections, most of this land has a high content of harmful salt and produces nearly valueless alkali grasses and shrubs. A few areas have been reclaimed and are used for the production of sugarcane.

Although the river flood plains definitely lie adjacent to the stream channels, the alluvial material has been spread out to such an extent at the mouth of each river that a band of this material not only extends continuously for many miles parallel with the coast but inland from the coastal lowlands as well. About 90 percent of all the river flood plains are within 5 miles of the coast. Generally speaking, these soils of the alluvial lands are deep, nearly level, dark, and fertile. Those adjacent to the streams, for the most part, are more friable, better drained, and sandier than those occurring parallel with the streams (but a short distance away from them) and associated with the poorly drained mineral soils of the coastal lowlands. Most of the soils of the alluvial lands range from only slightly acid to calcareous. The most alkaline soils occur along the arid southern coast where the materials have accumulated from soil washed from the limestone, calcareous tuff, shale, and hills of related material where the rainfall has not been sufficient to leach the lime carbonates from the soil. The most acid and lightest colored alluvial soils occur where the soil

material has been washed from the acid, coarse-textured, grantic hills in the eastern and the west-central parts of the island.

The soils of the river flood plains are nearly ideal for the production of sugarcane, as, for high yields, this crop requires soil that is nearly level, fertile, deep, properly drained and that will respond to good management and fertilizers. Nearly 90 percent of the area of these soils is planted to sugarcane. Most of the other 10 percent is used for the production of malojillo grass, which is used extensively for hay by the dairy farmers. This grass is about the only crop that can compete with sugarcane on this high-priced, valuable, productive land. Other crops, such as rice on the poorly drained soils and citrus, tobacco, corn, and minor crops on the well-drained soils, would be productive but not so profitable as sugarcane, under present conditions.

Nearly the entire area of the soils in the arid sections is irrigated, and considerable areas in the humid sections receive some water from pumps.

Adjacent to the river flood plains, but on slightly higher elevations, are the soils of the river terraces and alluvial fans. These soils are composed of materials similar to the alluvial material of the river flood plains, but they are older, genetically more developed, and never flooded from stream overflow. They are nearly level and occupy rather large areas. The soils are deep and fertile, and most of the areas are readily accessible. These favorable factors, combined with sufficient rainfall or sufficient irrigation water, make them well adapted for the production of high yields of sugarcane, provided they are well managed and fertilized. More than 75 percent of their area is used for this crop, because more profit is made from sugarcane than from any other crop, under present economic conditions. Some areas that occur at high elevations and far from sugar centrals are used for coffee, which produces profitable yields when the crop is well managed and the price is reasonably high. A few areas in the arid sections are not irrigated and therefore are used only as pasture land.

The soils of the smooth coastal plains form a discontinuous strip ranging in width from almost nothing along the southern and southeastern coasts to more than 8 miles along the north-central and northwestern coasts. Most of these soils are derived from medium-hard Tertiary limestone, and they are generally red or reddish brown, friable, deep, fairly fertile, permeable, and acid. They occur in level or undulating areas and range in texture from sand to clay. Because they have a wide range in texture; are deep, friable, and well drained; and allow rapid penetration of plant roots, they are adapted to nearly every crop grown on the island. Even with good management, however, they do not produce such high yields as do the soils on the river flood plains, terraces, and alluvial fans. These soils have been leached of their bases and plant nutrients to much greater extent than the soils on the river flood plains and the terraces, because they are older, more permeable, and, for the most part, more acid. They respond fairly well to large applications of fertilizers. Most of the areas receiving less than 60 inches of annual rainfall are irrigated.

The most profitable and, therefore, the most common practice is to plant sugarcane and pineapples on the heavy-textured soil types and grapefruit, minor truck crops, and cotton on the sandy-textured types. Both sugarcane and pineapples will grow on the sandy soils, but yields are much lower than on the heavier soils. Grapefruit

trees for best production need a deep, friable, well-drained, and well-aerated soil. Therefore, the sandy-textured soils of these smooth valleylike coastal-plain areas are nearly ideal for grapefruit. Generally speaking, minor crops and cotton are not very profitable, but in many places they are more profitable than any other crop that can be grown on the very sandy soils. Large acreages of the soils of the coastal plains are planted to sweetpotatoes, yuca, ñames, melons, and other vegetables. Guinea grass and elephant grass produce fairly good yields on these soils.

Areas of the soils of the smooth coastal plains, occurring in the semiarid northwestern part of the island near Isabela and in the southwestern part near Cabo Rojo, are the least acid soils of this group, because the rainfall is insufficient to leach rapidly all the calcium that is returned to the soil from the decayed plant leaves which have received the calcium from the soil through the plant's lower roots. The soils in this area are too alkaline for the profitable production of pineapples, but they are desirable for tobacco, peppers, cucumbers, eggplant, and other vegetables. They require considerable irrigation water for high yields of all crops. Corn, melons, and guinea grass yield fairly well without irrigation.

The soils of the inner plains and colluvial slopes lie adjacent to the uplands, and they do not form so distinct a band as the coastal lowlands, as they are somewhat intermixed with the uplands. In a general way, however, they form an irregular noncontinuous belt between the uplands and the other physiographic divisions. The relief of these soils ranges from gently sloping to strongly undulating, and, therefore, external drainage is adequate in most places. Internal drainage is somewhat restricted in most of the soils because they have very plastic sticky surface soils and subsoils that do not favor rapid percolation of water. Therefore, they are not seriously leached of their bases and plant nutrients. The heavy subsoils have such high water-holding capacity that they generally feel moist except during protracted dry spells.

Most of the soils in this group occur in humid or subhumid sections, and only a few areas are irrigated. A harmful quantity of soluble salts is a limiting factor in crop production in a very small proportion of their total area.

All the soils of the inner plains and colluvial slopes are fairly deep, are fertile, and contain very few rocks. Sugarcane and malojillo grass are the crops best adapted for these soils. For high yields of sugarcane, from 800 to 1,000 pounds of fertilizer to the acre are added each year, and most areas require some artificial drainage. These soils are too heavy and too plastic for such crops as citrus, tobacco, and cotton.

The soils of the uplands occupy the interior of the island, and in a few places they extend to the coast. In areas having a high rainfall, most of the soils occur on steep relief and are for the most part red or purple, high in clay, acid, and only fairly fertile. Pineapples, a crop requiring an acid well-drained reasonably deep soil, are grown to considerable extent on the rolling and smooth areas of these soils, especially in the vicinity of Corozal. Coffee, a crop that requires more than 65 inches of average annual rainfall and that produces the best quality of berries at an elevation ranging from 1,200 to 2,000 feet, is grown exclusively on these soils. Forests occupy most of the land

above an elevation of 2,000 feet, because at that elevation the relief is so rough, broken, and the soils so exposed to wind that commercial crops cannot profitably be grown. Oranges, bananas, plantains, yautia, and ñames are grown throughout areas of these deep red soils of the uplands, because the plants require considerable moisture and grow better in deep permeable soils than in heavy, plastic, or shallow soils.

In the subhumid sections, the soils of the uplands are grayish brown or brown, neutral, friable, and fertile. Most of these soils are fairly shallow and occupy areas of steep relief. Tobacco, a crop requiring a well-drained friable soil not influenced by salt breezes, is well adapted to these soils, and large areas in the central and east-central parts of the island are planted to this crop.

Subsistence crops, such as beans, pigeonpeas, corn, and sweetpotatoes, are planted throughout all areas of the brown or grayish-brown neutral or slightly acid upland soils. These crops generally are grown by the jibaros, or peon farmers, who do not have funds for the purchase of fertilizer or lime, and, under this system of management, these soils are more productive than the deeper, more acid, and more leached red soils of the uplands. Sugarcane is often planted on the more gentle slopes within a mile of a good highway. Probably a higher proportion of the rural population lives on these extensive grayish-brown uplands than on the soils of any other group. The reason for this is due, in part, to economic conditions in the island. Sugarcane is by far the most important crop grown, and, for the highest efficiency in handling it and for largest yields, it must be grown on good soils and in large holdings. Therefore, most of the nearly level deep fertile soils are used for that crop. The land occurs in large tracts and is sparsely populated. The population is increasing at the rate of about 50 people to the square mile every 5 years. As the best land is used for cash crops, pressure of the rapidly increasing population gradually forces the jibaros and their families (fig. 97) farther into the hills and mountains onto the more or less shallow soils, where they plant some subsistence crops, in order to supplement the wages they receive from part-time work in sugar centrals, tobacco-stripping shops, needlework shops, and other industrial plants.

The soils of the uplands in the arid sections, as well as the most shallow soils in the subhumid and humid sections, are dark, shallow, and fertile. Most of these soils are alkaline, rocky, and have very steep relief. Owing to the shallowness of the soil, rockiness or steepness of the land, or dry climate, or a combination of these factors, these soils are suitable only for grass, brush, and trees. Large cattle ranches and few people are characteristic of the arid sections, and small farms with very small patches of subsistence crops and large acreages of pasture and forest are typical of the subhumid and humid sections.

When the soils were mapped, stress was laid, not only on the different physical characteristics of the soil profiles, but also on some of the chemical characteristics, such as acidity and salt content, which have a bearing on crop use. The relief was considered, and steep or smooth phases of soil types were differentiated, which required different use of the land from that employed on the typical soil.

Very shallow alluvial soils underlain by gravel are shown as shallow soil phases, as these soils, when irrigated, may require more than five times as much water as the typical soil. Seriously eroded areas are shown as eroded phases.

The soils of some series, as Múcara, Catalina, Toa, Coloso, Fajardo, and Sabana Seca, occur throughout nearly all the humid parts of the island, and other soils, like the Dominguito and Juana Díaz, occur only in local areas.

The soils are arranged in several groups, based principally on the physiographic divisions in which they occur (fig. 98), and these

FIGURE 97.—Hundreds of families live on the shallow brown Múcara and related soils of the interior. The people plant subsistence crops, in order to supplement the wages they receive from part-time work in sugar centrals, tobacco-stripping shops, and other industrial plants.

Cientos de familias viven del suelo pardo poco profundo Múcara y de otros relacionados en el interior de la isla. La gente siembra frutos menores para suplementar los salarios recibidos de las centrales azucareras, despalillados de tabaco y otras industrias.

groups are subdivided on the basis of the soil characteristics that influence land use. The soils of the uplands have been placed in three subgroups, according to the depth to unconsolidated rock. These soils occupy nearly as much land as the combined area of all other soils. The relief of these soils ranges from rolling to precipitous; the largest acreage would be classified as very steep. Most of the coffee, oranges, bananas, vanilla, and the greater part of the tobacco and subsistence crops, as well as pasture grass, are grown on them. The soils of the inner plains occupy a small proportion of the total area. They have level, rolling, or sloping relief and are suitable for nearly all cultivated crops, but sugarcane occupies the largest acreage. The soils of the terraces and alluvial fans are divided into two subgroups, based on the compaction of the subsoils. These soils have

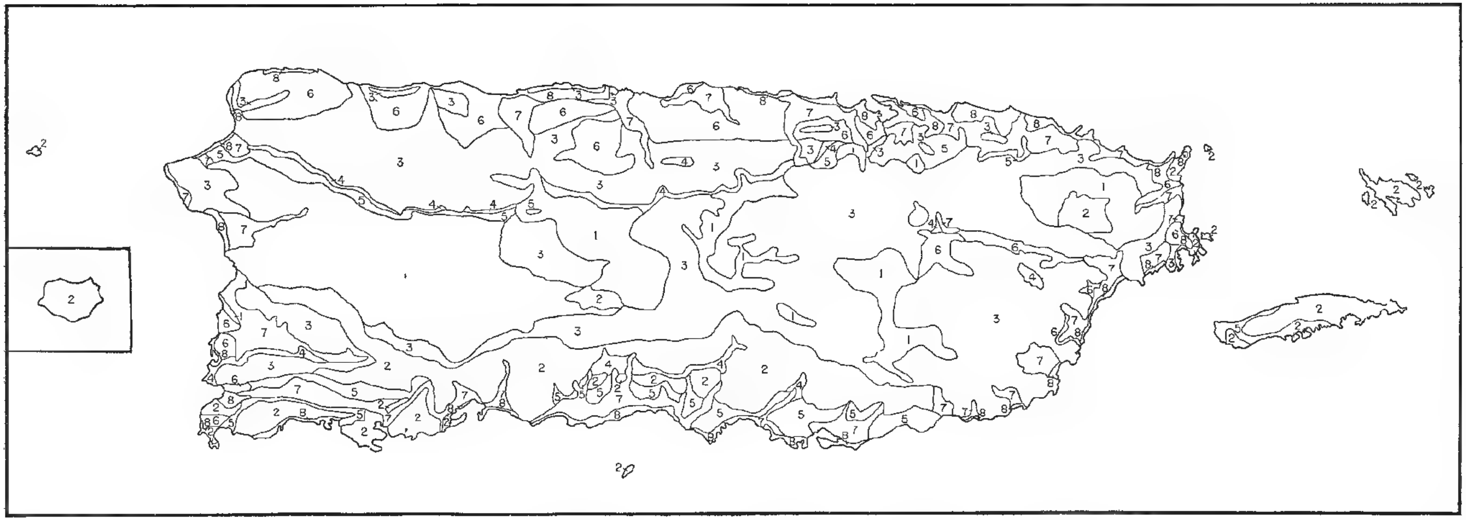

FIGURE 98.—Diagrammatic map of Puerto Rico, showing the approximate soil groupings and physiographic divisions: 1, Deep soils of the uplands; 2 shallow soils of the uplands; 3, medium-deep and some shallow soils of the uplands; 4, soils of the inner plains; 5, soils of the terraces and alluvial fans; 6, soils of the smooth coastal plains and, in places, some shallow soils of the uplands; 7, soils of the river flood plains; and 8, soils of the coastal lowlands.

Diagrama de Puerto Rico demostrando aproximadamente los grupos de suelos y divisiones fisiográficas: 1, Suelos profundos de la altura; 2, suelos poco-profundos de la altura; 3, suelos medio-profundos incluyendo algunos poco-profundos de la altura; 4, suelos de las llanuras interiores; 5, suelos abancalados y de aluvión en abanico; 6, suelos de las llanuras costaneras lisas incluyendo, en sitios, algunos suelos poco-profundos de la altura; 7, suelos de los valles de aluvión; y 8, suelos de los bajos costaneros.

nearly level relief and for the most part are high in fertility and are especially well adapted for sugarcane. The soils of the coastal plains are divided into four subgroups, according to the compaction of either the surface soil or the subsoil. These soils are fairly fertile and produce fair yields of nearly every crop commonly grown. They have level or undulating relief, and the majority of them are red or reddish brown. The soils of the river flood plains are divided into two subgroups, depending on the condition of internal drainage. Sugarcane, the most productive crop produced on these soils, occupies nearly 90 percent of their total area. They have level relief and are enriched frequently by silt-laden overflows which help to maintain their high fertility. The soils of the coastal lowlands are divided into three subgroups: Well-drained soils, imperfectly drained mineral soils, and imperfectly drained organic soils. Most of the land is level or flat, and the soils are fairly productive if they are not impregnated with salt or do not have a high water table. Nearly all of the coconuts and a large quantity of truck crops are produced on the well-drained areas of these soils. The organic and related soils include a very small proportion of the total area, and agriculturally they are not very important. Most of their area is in mangroves. Field observations are being made continually, regarding the use capabilities of each soil type; and this information, together with field notes on actual crop yields, as reported by farmers and experiment stations, combined with notes on the chemical and physical characteristics of the soil type, are the bases for the description of the soil types and phases discussed in the following pages. The accompanying soil maps show the location of the many soil types, and table 13 gives their acreage and proportionate extent.

TABLE 13.—*Acreage and proportionate extent of the soils mapped in Puerto Rico*

Type of soil	Acres	Percent
Soils of the uplands		
Catalina clay	38,336	1.8
Catalina clay, level phase	5,760	.3
Catalina clay, steep phase	58,112	2.7
Catalina stony clay	11,968	.6
Catalina stony clay, steep phase	4,672	.2
Cialitos clay	69,504	3.2
Cialitos clay, steep phase	131,840	6.0
Cialitos clay, eroded phase	8,320	.4
Los Guineos clay	52,416	2.4
Los Guineos clay, smooth phase	18,112	.8
Alonso clay	17,344	.8
Alonso clay, smooth phase	4,992	.2
Alonso clay, colluvial phase	192	(1)
Alonso clay, shallow phase	2,432	.1
Alonso silty clay loam	384	(1)
Alonso silty clay loam, colluvial phase	128	(1)
Malaya clay	512	(1)
Malaya clay, smooth phase	576	.05
Jayuya silty clay loam	4,096	.2
Jayuya silty clay loam, steep phase	5,632	.3
Nipe clay	2,880	.1
Colinas clay loam	17,856	.8
Colinas stony loam	8,640	.4
Colinas fine sandy loam	1,280	.1
Soller clay	5,632	.3
Tanamá stony clay, smooth phase	14,144	.7
Tanamá stony clay, colluvial phase	9,408	.4
Plata clay	2,816	.1
Plata clay, mixed phase	768	.05
Daguao clay	2,752	.1
Soils of the uplands—Con.		
Daguao clay, colluvial phase	1,728	0.1
Múcara silty clay loam	148,800	6.9
Múcara silt loam	6,528	.3
Juncos clay	31,360	1.4
Sabana silty clay loam	18,368	.8
Sabana silt loam	8,192	.4
Naranjito silty clay loam	11,136	.5
Naranjito silty clay loam, smooth phase	3,392	.2
Naranjito silty clay loam, colluvial phase	64	(1)
Río Piedras clay	9,472	.4
Río Piedras silty clay loam	192	(1)
Pandura sandy clay loam	15,680	.7
Pandura sandy clay loam, smooth phase	1,792	.1
Pandura loam	9,152	.4
Pandura loam, smooth phase	21,824	1.0
Cayaguá sandy clay loam	7,424	.3
Cayaguá sandy clay loam, steep phase	17,408	.8
Ciales clay loam	6,272	.3
Ciales clay loam, smooth phase	512	(1)
Ciales loam	2,496	.1
Ciales loam, smooth phase	2,304	.1
Ciales loam, colluvial phase	64	(1)
Teja loam	1,984	.1
Teja loam, steep phase	3,584	.2
Teja loam, eroded phase	192	(1)
Utuado loam	22,144	1.0
Utuado loam, smooth phase	3,200	.1

See footnote at end of table.

TABLE 13.—*Acreage and proportionate extent of the soils mapped in Puerto Rico*—Continued

Type of soil	Acres	Per-cent
Soils of the uplands—Con.		
Vieques loam	6,400	0.3
Vieques loam, undulating phase	1,472	.1
Vieques loam, colluvial phase	2,496	.1
Colinas clay loam, steep phase	20,544	.9
Colinas stony clay loam	6,400	.3
Colinas stony clay loam, steep phase	13,184	.6
Soller clay loam	3,456	.2
Soller clay loam, shallow phase	4,480	.2
Soller clay loam, hilly phase	20,672	.9
Soller clay loam, steep phase	33,024	1.5
Aguilita clay	9,600	.4
Aguilita stony clay	31,616	1.4
Aguilita stony clay, shallow phase	3,136	.1
Tanamá stony clay	89,600	4.1
Ensenada clay	768	.05
Ensenada clay, shallow phase	3,584	.2
San Germán clay	11,392	.5
Lajas clay	6,848	.3
Lajas clay, rolling phase	4,032	.2
Jácana clay	28,544	1.3
Descalabrado silty clay	49,344	2.3
Descalabrado silty clay, rolling phase	19,264	.9
Descalabrado silty clay, shallow phase	9,600	.4
Descalabrado silty clay, eroded phase	18,752	.8
Guayama clay	31,616	1.4
Guayama clay, colluvial phase	1,920	.1
Daguao clay, steep phase	896	.05
Múcara silty clay loam, steep phase	122,688	5.7
Múcara silty clay loam, shallow phase	44,352	2.0
Múcara silt loam, steep phase	20,928	1.0
Picacho stony clay loam	11,840	.5
Naranjito silty clay loam, steep phase	192	(1)
Yunes clay	3,712	.2
Yunes silt loam	960	.05
Mariana clay loam	6,400	.3
Juana Díaz clay loam	512	(1)
Juana Díaz silty clay	384	(1)
Rosario silty clay	22,208	1.0
Rosario silty clay, smooth phase	2,816	.1
Vieques loam, steep phase	3,584	.2
Rough stony land	10,624	.5
Soils of the inner plains		
Las Piedras clay loam	1,408	.1
Las Piedras clay loam, steep phase	576	.05
Las Piedras loam	1,344	.1
Mabí clay	22,784	1.0
Mabí clay, flat phase	4,416	.2
Moca clay	11,136	.5
Moca silty clay loam	3,136	.1
Moca silty clay loam, steep phase	128	(1)
Moca loam	1,024	.05
Dominguito clay	2,560	.1
Río Arriba clay	1,856	.1
Santa Clara clay	10,368	.5
Santa Clara clay loam	4,800	.2
Camagüey silty clay	2,560	.1
Camagüey clay loam	7,680	.3
Yauco clay	3,456	.2
Yauco clay, colluvial phase	1,792	.1
Ponceña clay	2,752	.1
Ponceña clay, eroded phase	512	(1)
Portugués clay	1,024	.05
Mercedita clay	1,920	.1
Barrancas clay	512	(1)
Barrancas silty clay loam	256	(1)
Pozo Blanco clay	320	(1)
Pozo Blanco clay loam	2,048	.1
Amelia clay	11,072	.5
Río Cañas clay	640	.05
Cabo Rojo clay	2,176	.1
Cabo Rojo clay, rolling phase	64	(1)
Soils of the terraces and alluvial fans		
Torres clay	3,520	0.2
Torres clay, steep phase	3,200	.1
Torres silty clay loam	1,216	.1
Vía silty clay	5,888	.3
Vía silty clay, broken phase	960	.05
Vía clay loam	1,664	.1
Vía silt loam	704	.05
Vía silt loam, broken phase	128	(1)
Lares clay	8,768	.4
Lares clay, steep phase	5,952	.3
Lares clay, red-subsoil phase	512	(1)
Lares silty clay loam	1,792	.1
Lares clay loam	4,288	.2
Lares sandy loam	1,088	.05
Fajardo clay	7,168	.3
Fajardo clay, gray phase	384	(1)
Fajardo clay, steep phase	1,408	.1
Humacao clay	1,408	.1
Humacao clay loam	896	.05
Humacao loam	1,856	.1
Humacao sandy loam	64	(1)
Mayo clay loam	64	(1)
Mayo loam	256	(1)
Resolución clay loam	256	(1)
Llave loam	1,472	.1
Llave sandy loam	704	.05
Arcadia loam	256	(1)
Coamo clay	6,464	.3
Coamo clay, alluvial-fan phase	320	(1)
Coamo silty clay loam	1,920	.1
Coamo silty clay loam, rolling phase	704	.05
Machete clay	960	.05
Machete clay loam	2,432	.1
Machete loam	64	(1)
Machete loam, steep phase	64	(1)
Vives clay loam	1,792	.1
Vives clay loam, colluvial phase	832	.05
Vives clay loam, steep phase	64	(1)
Vives loam	896	.05
Vives sandy loam	128	(1)
Fraternidad clay	11,072	.5
Fraternidad clay, shallow phase	64	(1)
Fraternidad clay, imperfectly drained phase	256	(1)
Fraternidad clay, colluvial phase	1,152	.1
Fraternidad clay loam	192	(1)
Paso Seco silty clay	5,120	.2
Paso Seco clay	1,344	.1
Paso Seco silty clay loam	3,136	.1
Paso Seco silt loam	192	(1)
Paso Seco loam	64	(1)
Fé clay	4,736	.2
Fé clay, imperfectly drained phase	2,176	.1
Santa Isabel clay	7,040	.3
Santa Isabel silty clay loam	3,904	.2
Santa Isabel loam	576	.05
Teresa clay	1,472	.1
Teresa silty clay loam	2,176	.1
Teresa loam	320	(1)
Candelero loam	1,536	.1
Candelero loam, shallow phase	704	.05
Candelero clay	64	(1)
Candelero clay, shallow phase	64	(1)
Candelero sandy clay loam	320	(1)
Candelero sandy clay loam, shallow phase	64	(1)
Candelero sandy clay loam, broken phase	128	(1)
Candelero sandy loam	1,408	.1
Soils of the coastal plains		
Sabana Seca clay	7,488	.3
Sabana Seca sandy clay loam	9,984	.5
Caguas clay	5,568	.3
Caguas sandy clay loam	256	(1)
Almirante clay	2,752	.1
Almirante sandy clay	3,584	.2

See footnote at end of table.

TABLE 13.—*Acreage and proportionate extent of the soils mapped in Puerto Rico*—Continued

Type of soil	Acres	Per-cent	Type of soil	Acres	Per-cent
Soils of the coastal plains—Con.			*Soils of the river flood plains*—Con.		
Almirante fine sandy loam	448	(1)	San Antón silty clay loam	4,864	0.2
Vega Alta clay, heavy-subsoil phase	1,408	0.1	San Antón clay loam	2,240	.1
Vega Alta sandy clay loam, heavy-subsoil phase	1,728	.1	San Antón silt loam	3,904	.2
Vega Alta clay loam, heavy-subsoil phase	1,216	.1	San Antón silt loam, shallow phase	1,088	.05
Vega Alta clay loam, poorly drained phase	64	(1)	San Antón loam	5,952	.3
Islote clay loam	960	.05	San Antón loam, shallow phase	3,392	.2
Islote sandy loam	1,152	.1	San Antón fine sandy loam	1,984	.1
Islote sandy loam, imperfectly drained phase	320	(1)	Altura clay	128	(1)
Coto clay, heavy phase	6,848	.3	Altura silty clay	384	(1)
Coto clay	4,672	.2	Altura silt loam	576	.05
Coto sandy clay	1,600	.1	Altura loam	2,240	.1
Espinosa clay	1,408	.1	Altura loam, shallow phase	1,280	.1
Espinosa sandy clay	10,432	.5	Coloso clay	11,712	.5
Matanzas clay	3,072	.1	Coloso clay, poorly drained phase	6,720	.3
Matanzas sandy clay	320	(1)	Coloso silty clay	14,976	.7
Bayamón clay	2,176	.1	Coloso silty clay loam	2,816	.1
Bayamón sandy clay	2,112	.1	Coloso clay loam	576	.05
Bayamón sandy clay loam	1,344	.1	Coloso silt loam	4,096	.2
Vega Alta clay	384	(1)	Coloso loam	832	.05
Vega Alta clay loam	3,840	.2	Fortuna clay	1,856	.1
Vega Alta sandy clay loam	1,472	.1	Fortuna clay, poorly drained phase	832	.05
Vega Alta fine sandy loam	5,504	.3	Fortuna silty clay loam	1,792	.1
Vega Alta loamy fine sand	2,624	.1	Fortuna clay loam	1,408	.1
Espinosa sandy loam	2,368	.1	Vega Baja clay	192	(1)
Espinosa loamy sand	2,560	.1	Vega Baja silty clay	3,968	.2
Coto loamy sand	256	(1)	Martín Peña clay	3,136	.1
Bayamón fine sandy loam	7,104	.3	Martín Peña sandy clay loam	2,176	.1
Bayamón loamy fine sand	832	.05	Talante clay	512	(1)
Maleza fine sandy loam	1,152	.1	Talante silty clay loam	320	(1)
Maleza loamy sand	1,856	.1	Talante clay loam	1,152	.1
Islote loamy sand	512	(1)	Talante loam	1,728	.1
Islote sand	704	.05	Talante sandy loam	832	.05
Río Lajas sand	2,880	.1	Talante fine gravel	128	(1)
Río Lajas sand, hardpan phase	128	(1)	Irurena clay loam	1,024	.05
Guayabo fine sand	2,624	.1	Irurena loam	256	(1)
Guayabo fine sand, shallow phase	5,888	.3	Yabucoa clay	384	(1)
Corozo fine sand	3,328	.2	Yabucoa clay loam	704	.05
Algarrobo fine sand	5,376	.3	Yabucoa loam	192	(1)
St. Lucie fine sand	2,496	.1	Josefa clay	2,688	.1
Soils of the river flood plains			Josefa clay loam	256	(1)
Toa silty clay	2,176	.1	Maunabo clay	704	.05
Toa silty clay loam	12,800	.6	Maunabo silty clay loam	64	(1)
Toa silt loam	11,584	.5	Maunabo clay loam	1,088	.05
Toa silt loam, low-bottom phase	704	.05	Maunabo loam	896	.05
Toa loam	5,632	.3	Vayas clay	640	.05
Toa fine sandy loam	3,776	.2	Vayas silty clay loam	1,664	.1
Toa fine sandy loam, low-bottom phase	3,968	.2	Vayas silt loam	1,024	.05
Estación silty clay	384	(1)	Vayas loam	320	(1)
Estación clay loam	512	(1)	Aguirre clay	9,344	.4
Estación silt loam	3,072	.1	Aguirre silt loam	64	(1)
Estación silt loam, low-bottom phase	320	(1)	Guánica clay	5,696	.3
Estación loam	2,752	.1	*Soils of the coastal lowlands*		
Estación sandy loam	1,152	.1	Cataño loamy sand	3,840	.2
Riverwash	6,592	.3	Cataño loamy sand, shallow phase	1,344	.1
Viví clay	128	(1)	Cataño sand	6,848	.3
Viví silty clay loam	128	(1)	Aguadilla sandy loam	576	.05
Viví clay loam	384	(1)	Aguadilla loamy sand	2,880	.1
Viví clay loam, shallow phase	64	(1)	Aguadilla sand	960	.05
Viví silt loam	128	(1)	Palm Beach sand	1,152	.1
Viví loam	3,904	.2	Coastal beach	1,600	.1
Viví loam, shallow phase	704	.05	Dune sand	1,024	.05
Viví sandy loam	1,920	.1	Meros sand	3,968	.2
Viví loamy sand	320	(1)	Jaucas sand	768	.05
San Antón clay	1,088	.05	Piñones clay	4,544	.2
San Antón silty clay	960	.05	Piñones silty clay	1,472	.1
San Antón silty clay, shallow phase	192	(1)	Piñones sandy clay loam	1,280	.1
			Palmas Altas clay	5,888	.3
			Palmas Altas silty clay	128	(1)
			Palmas Altas silty clay loam	192	(1)
			Palmas Altas sandy clay loam	1,728	.1
			Palmas Altas loam	448	(1)
			Úrsula clay	1,088	.05
			Cintrona clay	576	.05

See footnote at end of table.

TABLE 13.—*Acreage and proportionate extent of the soils mapped in Puerto Rico*—Continued

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Soils of the coastal lowlands—Con.			*Soils of the coastal lowlands*—Con.		
Cintrona silty clay loam	3,840	0.2	Cataño loamy sand, poorly drained phase	128	(1)
Cintrona loam	704	.05	Cataño sand, poorly drained phase	576	0.05
Serrano clay	6,976	.3	Meros sand, saline phase	256	(1)
Serrano sandy clay loam	1,344	.1	Tiburones muck	6,848	.3
Serrano loam	1,088	.05	Saladar muck	8,000	.3
Serrano sandy loam	256	(1)	Saladar muck, shallow phase	1,152	.1
Córcega sandy clay	1,408	.1	Peat	7,360	.3
Córcega sandy clay, poorly drained phase	64	(1)	Peat, shallow phase	1,280	.1
Córcega sandy loam	960	.05	Piñones clay, peaty-subsoil phase	3,136	.1
Córcega sandy loam, poorly drained phase	256	(1)	Sinkholes	64	(1)
Aguadilla sandy loam, poorly drained phase	448	(1)	Reparada clay	2,560	.1
Aguadilla loamy sand, poorly drained phase	448	(1)	Total	2,165,120	

[1] Less than 0.05 percent.

SOILS OF THE UPLANDS

The soils of the uplands include such a large proportion of the center of the island that they may be referred to as the backbone of Puerto Rico. The soils in this division have a wide range in soil characteristics. They range from black to nearly white, from rich to poor, from acid to alkaline, from fine sandy loams to clays, from shallow to deep, and from young to old. The soil climate ranges from arid to humid and the elevation from near sea level to more than 4,000 feet above. This may seem too great a variety of conditions for one soil division, but by separating the soils within this division into three subgroups, on the basis of the depth of their profiles, it may be seen that a correlation exists between each of the three groups and the land use and crop adaptation.

DEEP SOILS OF THE UPLANDS

The deep soils of the uplands include 21 soil types and phases of the Catalina, Cialitos, Los Guineos, Alonso, Malaya, Jayuya, and Nipe series. These soils occur throughout the entire humid section of the interior, and they range in elevation from less than 100 to about 3,000 feet above sea level. All the soils in this subgroup, with the exception of the Jayuya soils, have been derived from fine-grained volcanic igneous rocks that have decomposed rapidly under the warm, moist tropical climate, thereby producing soils that are high in permeable clay and low in silt and sand. The soils are high in iron and aluminum content, and the silica content is low. All these soils are either red or purplish red. The surface soils are acid and friable and readily work to a good seedbed. The subsoils in general are very acid, heavy, but permeable, and are adequately drained. On a given rock the thickness of the subsoil and substratum increases with an increase in the average annual rainfall and also on the more gentle slopes.

Most of the soils in this group occur on steep hills, and numerous V-shaped drainageways dissect their entire area. Many of the soils are planted to clean-cultivated crops, regardless of the steepness of the slopes, and through improper management much of the surface soil is lost through erosion, although these soils are not susceptible to

erosion on ordinary slopes of 10 or 15 percent. After heavy rains, streams throughout areas of the cultivated steep hillsides soon become loaded with red and purple clay. As soil development is rapid, in many places it keeps pace with erosion. In the moist warm climate, vegetation grows rapidly, thereby keeping erosion to a minimum, except on the improperly cultivated hillsides. The run-off water on most farms has a steep but short course before it empties into grass-covered healed-over ravines or small rock-bottomed streams (fig. 99).

These soils, with the exception of the Jayuya and Nipe, have some large rocks on the surface and throughout the soil layers. Areas

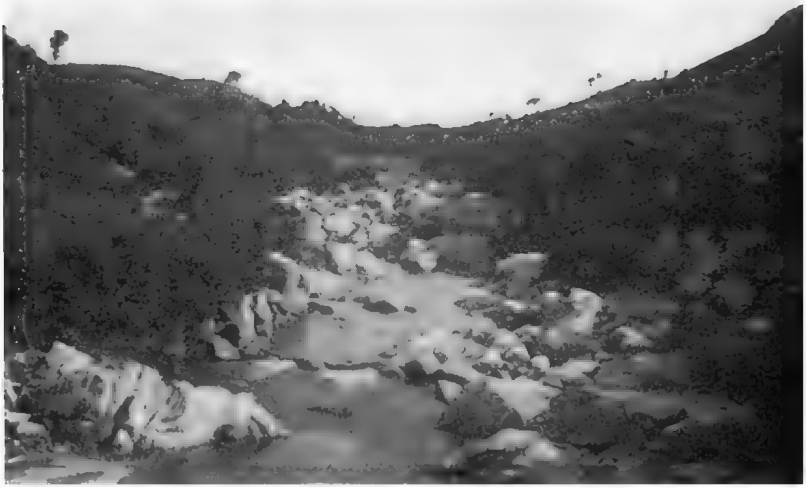

FIGURE 99.—Typical stream in the humid section.
Río típico en la zona húmeda.

shown on the map with stone symbols and the stony soil types contain much larger quantities than the typical areas.

Physically, these soils are adapted to many crops, but, owing to a deficiency in such chemical compounds as lime, phosphorus, and magnesium, to their rough relief, high elevation, and in many places to their long distance from towns and highways (fig. 100), coffee, oranges, bananas, and timber are the principal crops. Citrus, pineapples, and sugarcane are important crops in the smoother lower areas adjacent to roads.

Based on their natural productivity, the Alonso soils are the strongest, followed in order by the Malaya, Catalina, Jayuya, Cialitos, Los Guineos, and Nipe. The latter soils are exceedingly low in productivity. The steeper the relief, the less productive and less desirable are these soils. In equal areas, crop production generally is about four times greater on concave slopes than on convex slopes. Coffee that yields 100 pounds to the acre on convex slopes yields from 400 to 600 pounds on concave slopes. The soils on the concave slopes are higher in organic matter and have thicker surface layers than those on the convex slopes, owing to a gradual accumulation of soil and plant remains that wash from the adjacent slopes. The concave slopes also

are better protected from the wind, and the soils have a higher content of soil moisture than those on the convex slopes.

The smooth phases of these soils are more desirable and are adapted to a greater variety of crops than the typical soils. Unless the level areas receive large quantities of fertilizers, they are, in general, less productive than the gently rolling areas, because they are leached to a greater extent, are more acid, and have slightly poorer internal drainage. The colluvial slopes are generally the most desirable areas of all the soils of this subgroup, especially if they occur below areas of Múcara or related alkaline soils, as the wash from the alkaline soils

FIGURE 100.—Typical view on Catalina clay. This soil is deficient in lime, phosphorus, and magnesium, and the crops produced apparently are low in nutritive value. Poor teeth and rickets are common among the people living on areas of this soil. This particular area has an average annual rainfall of about 90 inches and is about 4 miles from the nearest road. Coarse matojo grass in foreground.

Vista de Catalina arcilloso. Este suelo está deficiente en calcio, fosforo, y magnesio, y los cultivos producidos en él aparentemente son bajos en valor nutritivo. Dientes enfermos y raquitismo son corrientes entre la gente que vive en áreas de este suelo. Esta área tiene una precipitación anual de más o menos 90 pulgadas y está a más o menos a 4 millas de la carretera más próxima. Al frente, matojo.

tends to keep the red soils from becoming very acid, and the incorporation of freshly eroded material from the higher slopes increases the productivity of the red soils.

Catalina clay.—Catalina clay is one of the most extensive all-round farming soils in the uplands. It is one of the red friable clay soils distributed over the ridges and slopes in areas receiving more than 79 inches of average annual rainfall and where the most important soil-forming rocks are andesitic tuff and tuffaceous shale. This soil occurs in large areas south of San Juan, Corozal, and Morovis; south of Ciales; and east of Mayagüez and Añasco. The relief ranges from rolling to steep, but most of the hills are rounded, and gently sloping ravines intervene.

A cultivated field of Catalina clay ranges in color from red to light brown. Few of the large fields are uniform in color, because deep plowing and sheet erosion have exposed the red subsoil that lies below the original brown or reddish-brown surface soil, and the result is a heterogeneous color. Normally, the surface soil is light reddish-brown friable softly granular clay that forms large clods when plowed, but which soon slakes into fine granules after the first or second dashing tropical shower. The thickness of the surface soil, as well as the value of the land, varies with the relief. On the less valuable, steeper, more eroded slopes the surface soil does not average more than 4 inches in thickness, and when the land is plowed some of the subsoil is exposed. On the more rolling, more valuable, less eroded areas, the surface soil is generally about 8 inches thick. The upper part of the subsoil, ranging from a depth of 8 to a depth of 24 inches, is brownish-red or red heavy but friable slightly granular clay. Both the surface soil and the subsoil are penetrated readily by plant roots and percolating water, and as a consequence sheet erosion is less severe than on soils with more plastic subsoils, which absorb water more slowly.

The lower part of the subsoil, beginning at a depth of about 24 inches, is dark-red clay that is more friable than the material in the layers above. The uniform red clay continues to a depth ranging from 10 to 30 feet, before the parent rock is reached. This soil is acid in the surface soil and becomes much more acid with depth.

Mechanical analyses show that this soil is high in clay and low in sand and silt. The surface soil contains over 65 percent of clay; the subsoil, about 80 percent; and the lower substratum, about 70 percent. Catalina clay is friable, only slightly plastic, lateritic clay that does not crack greatly at extremes of moisture content, and it can be cultivated soon after a rain without harming its physical characteristics. It is not so friable as Nipe clay or Matanzas clay, which occur in both Puerto Rico and Cuba.

Catalina clay is fairly productive for a variety of crops. At elevations ranging from 1,000 to 1,500 feet, nearly the entire area is used for the production of coffee. Yields exceeding 400 pounds to the acre of dry coffee may be expected in normal years from well-managed coffee farms. The yields are highest on the concave slopes and near the bases of the southern and western sides of long sloping hills. This soil is well adapted to the growing of guava, guama, and moca trees for shade in the coffee plantations. It is considered one of the best soils for the production of coffee, because both the shade trees and the coffee trees grow rapidly, owing to the friability of the soil and its medium-high content of plant nutrients. The soil occurs only in areas having sufficient rainfall for the growing of coffee, and large areas lie at an elevation that is nearly ideal for this crop.

Other crops producing well on this soil at high elevations are bananas, plantains, oranges, and yautias. The trees of inferior quality growing on this soil are made into charcoal. The making of charcoal returns considerable income, but it is a poor practice so far as improvement of the natural resources is concerned.

At elevations below 500 feet, many acres of this soil are used for the growing of grapefruit trees. The soil, although high in clay, is sufficiently permeable for roots to penetrate deeply, and the trees produced have a wide branch spread, thus filling in the spaces between

the trees. This, in turn, shades the ground and prevents the growth of weeds. The common practice is to plant from 42 to 45 grapefruit trees to the acre, and the trees on this soil continue to produce to an old age. One 17-year-old orchard, under fertilization and proper management, is producing yearly from 11 to 20 boxes of fruit to the tree. Fertilizer is applied to this orchard at a rate of 1,500 pounds to the acre. The proportion of ingredients used is 1 ton of sulfate of

FIGURE 101.—Catalina clay along a highway near Corozal, where some fertilizer is used. Subsistence crops, such as sweetpotatoes, yautias, bananas, and pigeonpeas, planted on the 50-percent slope in the foreground. Pineapples and pasture in the background.

Catalina arcilloso a lo largo de una carretera cerca de Corozal donde se aplica algún abono. Frutos menores tales como batatas, yautías, guineos y gandules, al frente, sembrados en un declive de 50 por ciento. Piñas y pastos al fondo.

ammonia, 1 ton of acid phosphate, and one-half ton of potash. Two applications are made each year. Grass is grown in the orchards, in order to prevent erosion. The grass and weeds are cut with a machete at the beginning of the dry season.

Probably a larger acreage of this soil is planted to pineapples than of any other soil type on the island. On slopes (fig. 101) of 40 to 50 percent nearly as high yields are produced as on the undulating areas. In many places on the steep slopes the surface soil has been washed

away by erosion, but, with high applications of fertilizer, the subsoil of this soil is nearly as productive for pineapple as is the original surface soil. In many places, pineapples are planted in rows that run up and down the hills, but a much better practice is to plant with the contour of the land. This soil produces an average acre yield of about 300 crates of pineapples the first year, 250 crates the first ratoon, and 200 crates the second ratoon. The most common practice is to apply about 1,000 pounds of 6–8–10 fertilizer an acre in two applications. The largest acreage of pineapples planted on this soil is in the vicinity of Corozal and southeast of Morovis. The Red Spanish is the most important variety grown.

Sugarcane is often planted on this soil wherever it is within economical hauling distance from a sugar central. Sugarcane yields from 30 to 40 tons an acre gran cultura and 25 tons in ratoon cane. The P. O. J. 2878 variety does very well on this soil. In some places Mayagüez 28 produces very well, as it has very prolific stools. The common fertilizer practice is to apply the nitrogen in the form of ammonium sulfate but, as this soil is acid, probably sodium nitrate would be the better fertilizer to use (*9*).

American tomatoes and flowers, especially roses, grow very well, but such leguminous crops as beans and pigeonpeas do not produce very well as the soil is somewhat too acid.

Catalina clay, level phase.—Areas of Catalina clay in which the relief ranges from nearly level to slightly undulating are classified as Catalina clay, level phase. Most of this soil occurs on the high peneplain near Aibonito, in the terracelike area north of Cidra, and in a few areas south of Bayamón and Río Piedras. Owing to the nearly level relief, this soil has not been affected by sheet erosion, and the normal soil-forming processes have been acting unmolested on it for a long time. It differs from the typical soil, in that it has a thicker more acid surface soil and a slightly more compact lower subsoil layer, causing slightly restricted internal drainage, which is reflected by the mottled gray, reddish-brown, and red coloring of the normally red lower subsoil layer. This soil is leached of its plant nutrients to a slightly greater extent than is the typical soil. The farmers accustomed to using fertilizer prefer this soil to the typical soil for most crops, but those who do not use fertilizer consider this soil inferior to the more rolling areas.

Sugarcane yields from 40 to 50 tons an acre gran cultura, from 25 to 30 tons first ratoon, and from 20 to 25 tons second ratoon. Such high yields require the use of a large quantity of fertilizer. At the time of the survey one progressive farmer was using 1,000 pounds of 12–6–5 to the acre. The first crop of pineapples yields about 250 crates an acre, and the ratoon crops are much less. Other crops yield slightly less than on the typical soil unless they are more heavily fertilized. The large area north of Cidra is producing many kinds of truck crops, pineapples, sugarcane, and some grapefruit; and the area near Aibonito is largely in grass, coffee, and trees. Probably the largest acreage of this soil is used for sugarcane, and the rest is used for pasture, pineapples, minor crops, trees, and citrus.

Included with this soil on the map are several small areas, lying at an elevation of more than 2,000 feet, that are more poorly drained, lighter in color, and more acid than this soil. Most of these areas are used for forestry and the production of coffee. Trees are well

adapted to this included soil, but yields of coffee are low because of the high elevation and poor internal drainage of the land.

Catalina clay, steep phase.—Areas of Catalina clay that occur on slopes exceeding 50 percent are mapped as Catalina clay, steep phase. The color and soil characteristics of this soil and the typical soil are very similar. Soil of the steep phase has a slightly thinner surface soil because when the land is cultivated it erodes to a greater extent. The two soils are so interlaced in many places that the boundaries between them are drawn arbitrarily.

Catalina clay, steep phase, occupies large areas of the steep hills in the interior where the average annual rainfall is greater than 85 inches. Agriculturally, this soil is less desirable than the typical soil, and about 60 percent of it is used for pasture and trees; 30 percent for the growing of coffee, bananas, plantains, and oranges, and 10 percent for the production of minor truck crops. Yields in general are less than on the typical soil, but the concave slopes of this soil are more productive than the convex slopes of Catalina clay. This steep soil is considered good for the production of coffee, which yields 200 pounds an acre in favorable years on well-managed coffee farms. On many farms, however, only 30 or 40 pounds an acre are obtained.

This soil requires much more careful management than the less steep slopes in order to produce high yields of crops, as erosion is a factor that must receive serious consideration on any cultivated hillside having a slope ranging from 60 to 100 percent. Generally, the steeper the slope the less the yield. In many areas, land having a slope of more than 100 percent is planted to coffee which yields fairly well, but the coffee pickers must take precautions so that they will not fall down the hills. As might be expected, drainage is adequate or excessive. Nearly all of the streams throughout areas of the Catalina soils are continuous throughout most of the year, unless an unusual drought occurs. Most of the houses on this steep soil are located on the ridges of the hills, but many are on the concave slopes. Generally a few subsistence crops, such as sweetpotatoes, yautias, ñames, bananas, and plantains, are planted near each house. These plants produce very well, especially on the concave slopes and in places where refuse from the house is used as a soil amendment.

Pasture grass grows rank and coarse (fig. 101), but it has less nutritious feeding material than the grass in the dry sections. From 2 to 5 acres are required to pasture an animal throughout the year. The grass seems to grow about as well during the summer as during the drier, winter months.

Catalina stony clay.—Areas of Catalina clay that have an excessive number of rocks on the surface are classified as Catalina stony clay. Most areas of this soil are too stony for the profitable use of large farm implements, but cultivation by hand is carried on regardless of the rocks. Some of the rocks are more than 15 feet in diameter, but the majority are about 2 feet in diameter and are egg-shaped. When they weather, a veneerlike layer scales off. One of the largest areas of this soil is at the base of Sierra de Luquillo.

Catalina clay and Catalina stony clay are similar in color and soil characteristics. Owing to its high stone content, Catalina stony clay is used mostly for trees, coffee, and pasture and to only a small extent for cultivated crops. Tree production equals that on the

typical soil. These two soils are so intermingled in many places that no attempt is made to separate small areas of the stone-free soil from the stony soil, or vice versa.

Catalina stony clay, steep phase.—Catalina stony clay, steep phase, is the poorest soil of the Catalina series for all agricultural crops. It is used almost entirely for forestry. Trees grow very well, as the annual rainfall usually exceeds 90 inches, and the soil material is fairly deep, although it occurs on very steep relief. The depth to the unconsolidated rock is not quite so great as it is in areas of either Catalina stony clay or Catalina clay. Except for the thickness of the surface soil, this soil differs from the typical stony clay only in relief. In places rocks lie on the surface, and rock outcrops are numerous.

Agriculturally this soil is only slightly better than rough stony land. The cutting of wood for the making of charcoal is the main enterprise on this steep soil, especially after the virgin timber has been cut and sold.

Cialitos clay.—Cialitos clay is associated with Catalina clay and the related red and purple soils of the uplands. This soil is distributed over the entire area that is underlain by vulcanic tuffs and shale beds, where the average annual rainfall is greater than 75 inches. The soil occurs both on slopes and on the ridges of hills having less than 60-percent slope. It is similar in many respects to Catalina clay, but it has a lighter brown surface soil, a much heavier more plastic upper subsoil layer, and a lighter red lower subsoil layer. It is characterized by a light grayish-brown or brownish-red friable finely granular clay surface soil, which extends to the average depth of plowing, where it gradually changes to yellowish-red or red, medium heavy but permeable, plastic clay that swells and cracks to some extent when at the extremes of moisture content. At a depth of about 20 inches the soil is much more friable and is light yellowish-brown or light brownish-red clay. In places it has a tendency to have a mottled yellowish-brown and light brownish-red color, which indicates that internal drainage is not so good as in the Catalina soils, as, with the exception of the level phase of Catalina clay, they are not mottled.

This soil varies greatly within short distances. In places the subsoil is yellow, and rock fragments are present throughout all layers and even on the surface. In other places the surface soil is shallow, owing to sheet erosion. In some areas, the reddish-brown subsoil may continue to a depth of 30 inches before the friable yellowish-red lower subsoil layer is reached. In all places this soil is acid, becoming more strongly acid with depth. A plowed field may show many colors. In most places the eroded areas appear yellowish brown or reddish brown, and the noneroded areas are grayish brown. In virgin areas the surface layer is grayish brown or dark grayish brown. Trails through pastures appear red from a distance.

This soil occurs in large areas near Adjuntas in the coffee district, and south of Bayamón and Río Piedras. In the coffee district about 40 percent of this soil, including almost all of that on the concave and long gentle slopes, is used for the production of coffee. In such areas the yields are nearly as good as on Catalina clay. Most of the remaining 60 percent, including nearly all of the ridges (fig. 102) and convex slopes, is in grass which has low nutritive value. These latter areas have shallow surface soils and are not very productive unless heavily

fertilized. Sometimes sweetpotatoes, ñames, and yautias are planted. The areas south of Bayamón and Río Piedras are planted to sugarcane, citrus, and subsistence crops. Sugarcane produces about 30 tons to the acre when the land is sufficiently fertilized and well managed. Citrus does not grow so well as on Catalina clay. The pasture grasses grown on these lower lying areas, which have less rainfall, are better than those produced in areas of high rainfall. Generally, 1½ acres will pasture an animal during the year.

The area of this soil that is surrounded by limestone, between Ríos Tanamá and Grande de Arecibo, apparently is the remnant of higher land that was not covered with limestone during submergence or, if it were, the limestone has been completely removed. Most of this area is used for pasture and such subsistence crops as sweetpotatoes, ñames, and yautias.

In average years and with good management, this soil will produce acre yields of about 1,500 pounds of sweetpotatoes, 3,500 pounds of

FIGURE 102.—Cialitos clay in the vicinity of Maricao. The ridges are cleared of timber, planted to subsistence crops for a few years, and then allowed to grow up to grass and eventually revert to brush.

Cialitos arcilloso en la vecindad de Maricao. La cresta de los montes ha sido despojada de bosques, sembrada de frutos menores por varios años y abandonada a pastos; luego se cubre de maleza.

ñames, 1,500 pounds of yautias, 250 pounds of beans, 200 pounds of pigeonpeas, 6 bushels of corn, and from 40 to 200 pounds of coffee.

Cialitos clay, steep phase.—Areas of Cialitos clay that occur on slopes greater than 50 percent are mapped as a steep phase of the typical soil. This steep soil has the same physical and chemical characteristics as Cialitos clay, but, owing to its relief, it is not so desirable or so productive. More than 50 percent of the land is idle or in pasture, and most of the remainder is in coffee. This soil is closely associated with the typical soil and is well distributed throughout all the humid sections where the parent material is dominantly tuff. It is one of the more extensive soils of the uplands, and the prosperity of future generations will depend to some extent on the manner in which this and related soils are managed. This soil requires fertilizer

and lime for best yields, also care in preventing loss from erosion when planted to clean-cultivated crops. Ñames and yautias are better crops for the prevention of erosion than corn, beans, and pigeonpeas. The holes in which the yautias are planted act as catch basins and retard the force of the running water. The mounds in which the ñames are planted also check the force of the run-off.

Some upland rice planted on this soil produces about 200 pounds to the acre. The rice generally is planted in March or April and is harvested within 8 months.

Areas of this soil shown on the soil map with stone symbols are much less productive than the typical areas.

Cialitos clay, eroded phase.—With the exception of Nipe clay, Cialitos clay, eroded phase, is the poorest deep upland soil. This soil probably is derived from intrusive volcanic lavas. The relief is hummocky, irregular, and steep. Many of the hills, especially those adjacent to deeply eroded foot and horse trails, have high vertical cliffs.

This soil is characterized by a 4- to 8-inch reddish-brown massive medium plastic strongly acid clay surface soil. It is underlain by red permeable massive strongly acid clay, which gradually changes to mottled red, yellow, and gray friable permeable clay having a lifeless ashy feel. This layer continues to a great depth. The mottled color seems to be due to the character of the parent material, as the soil does not have restricted drainage. The clay content of a representative sample gradually decreases from 77 percent in the surface layer to 50 percent at a depth of 4 feet, and the silt content increases from 17 percent in the surface soil to 41 percent at a depth of 4 feet. The pH value is 4.7 throughout the profile. This soil, according to chemical analysis of a typical sample, contains only 0.06 percent of potassium, 0.07 percent of phosphorus, 0.06 percent of magnesium, 0.12 percent of calcium oxide, and only 0.15 percent of nitrogen in the topmost 6 inches. The underlying layer also is deficient in plant nutrients. The unusually low content of important chemical compounds, combined with the acid reaction, probably is responsible for the low fertility of the soil. The total soluble salt content is low, as are also the chromium and selenium contents. The highest content of selenium occurs at a great depth. This soil is not eroded to the same extent as are many soils in the United States, but it is about as unproductive as the seriously eroded soils of the southern Piedmont.

Within the large area of this soil south of San Sebastián are many tax delinquencies and many unpaid farm mortgages. The farmers consider this soil nearly worthless. It is valued at a price ranging from $2 to $5 an acre, although nearby soils, such as Catalina clay and Múcara silty clay loam, are valued between $35 and $45 an acre. This area has been neglected for years because the small landowners have had no incentive to build up their land. Therefore, most of the organic matter has been used by crops or has been lost through erosion, and little or none has been returned to the land. Erosion, both sheet and gully types, has left its effect on this soil more than on any other deep soil in the humid parts of Puerto Rico. Most of this area is several kilometers from a good highway, which fact also has its effect in lowering the value of the land and makes liming and fertilizing very expensive.

More than 70 percent of the total area of this soil is either idle or in pasture. The grass produced is of low feeding value. Cows pastured on this soil do not give sufficient milk for their calves, even though one cow may have from 4 to 5 acres of grass over which to graze. The grass grows rank and dense, but it seems to contain very little nourishment. Generally the lower parts of the long gentle slopes are the only areas cultivated. In such areas, sugarcane, yautias, bananas, coffee, and plantains grow fairly well, if the land is fertilized. Liming and fertilizing of this soil probably would increase crop yields from 50 to 100 percent.

A characteristic feature of the soil is the presence of large black rocks which occur in isolated groups, both on the hilltops and on the slopes. ` Magnetic oxide of iron is conspicuous along most of the trails and roads, where a sorting of material has taken place during heavy rains. Gullies are numerous along most of the foot trails. The dominant vegetation, especially on acid-poor land, includes several varieties of wild ferns, matojo, and icaco. Coconut palms will grow, but they produce only a few small nuts.

Los Guineos clay.—Los Guineos clay is closely related to the Catalina and Cialitos soils, but it is developed at higher elevations where the weather in general is cooler, wetter, and windier than in areas of the other red and purple soils of the uplands.

This soil occurs on steep or very steep relief and is characterized by a 6- or 8-inch grayish-brown slightly granular medium plastic strongly acid clay surface soil and a 3- to 6-inch brownish-yellow clay subsurface soil that abruptly changes to red plastic but permeable strongly acid clay. This layer gradually gives way, at a depth ranging from 3 to 4 feet, to lighter red more friable acid clay. Some rocks are on the surface of this soil and throughout the soil layers.

Areas of this soil indicated on the map by rock-outcrop symbols are of low value except for forestry. The slopes in such areas generally are very steep, and stone and rock outcrops are so numerous that it is practically impossible to cultivate the land, except with hand implements. The rocks, which occupy a fairly high proportion of the total area, reduce the value of this soil for crops or even for trees.

Within areas of this soil are many small narrow strips adjacent to and at the heads of drainageways, that have a gray plastic sticky acid clay surface soil underlain at a depth ranging from 8 to 14 inches by mottled gray and rusty-brown plastic acid clay that has imperfect internal drainage. Surface drainage also is inadequate for most cultivated crops. Seepage water from higher land often collects on these imperfectly drained areas which are used for forestry and to a limited extent for the production of malangas and yautias.

Probably about 50 percent of the total area of this soil is used for forestry. The valuable trees are cut for timber, and the poor-quality woods are used for the making of charcoal, which is an important enterprise within this area. Probably about 30 percent of the land is used for the production of coffee. The quality of the coffee is better than that grown on the Catalina soils, but the quantity produced is generally less than that produced at lower elevations. In the growing of coffee, the risk of damage from hurricanes is greater than on the lower lying soils, such as the Cialitos and Catalina. Large tracts of Los Guineos clay at one time were in productive coffee plantations,

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but at present, owing to the destruction of the coffee and shade trees caused by hurricanes, they are abandoned and produce only rank, coarse grasses of low feeding value and a variety of trees, some of which are valuable and others nearly valueless (fig. 103).

Los Guineos clay, smooth phase.—Areas of Los Guineos clay that have smooth or rolling relief are classified as a smooth phase of that soil. The smooth phase is much less extensive than the typical soil, but it occurs throughout almost all of the higher areas. Owing to its smooth relief, it has a deep surface soil, in places over 12 inches thick. The subsoil, especially in the more level areas, has a tendency to have a mottled gray, red, and brown color.

This soil is used more extensively for cultivated crops than is the typical soil, but probably more than 40 percent of its area is in grass. The main crops grown are tobacco, yautias, and coffee. All yields are low unless the land is carefully managed and heavily fertilized.

FIGURE 103.—Vegetation on Los Guineos clay. The vegetation is dense and grows rapidly, thereby keeping erosion to a minimum.

Vegetación en Los Guineos arcilloso. La vegetación crece espesa y rápidamente y mantiene la erosión a un mínimo.

Alonso clay.—Alonso clay is an extensive upland soil that is easily identified by its brownish-purple color. Most of it is derived from reddish-purple igneous rocks, but part of the material probably is derived from Cretaceous limestone, as many areas are closely associated with Cretaceous limestone outcrops. The soil occurs on hills having slopes ranging from 30 to 60 percent.

This soil has a brownish-purple friable permeable clay surface soil about 6 inches thick, underlain by friable granular reddish-purple clay, which rests on rock at a depth ranging from 20 to 60 inches, depending on the slope, amount of rainfall, and character of the rock. Generally speaking, the steeper the slope and the less the rainfall, the shallower is the soil. Alonso clay has characteristics similar to the very slightly plastic Catalina soils previously described and the nonplastic Matanzas, Nipe, and Maleza soils to be described later. Water penetrates this soil very readily, and very little rain is lost

through run-off unless the surface is very steep or the land is in clean cultivation. Plant roots are able to penetrate to the depth of the underlying porous rock, and in places they may penetrate it.

Alonso clay occurs in fairly large areas in the interior of the island, where the average annual rainfall ranges from 80 to 100 inches. Some of the larger areas are on both sides of Río Cialitos, southwest of Ciales, between Adjuntas and Maricao, and in other parts of the present coffee district. This soil is considered very desirable for the production of coffee. When properly managed, it yields from 300 to 600 pounds of coffee to the acre. Farmers prefer it to the red slightly more plastic Cialitos and Los Guineos soils for all crops. Coffee seems to grow faster on Alonso clay than on the other upland soils, but the life of the trees generally is not so long as on some of the other good coffee-producing soils. Most of this soil is planted to coffee, oranges, bananas, and plantains.

In many places this soil is not so acid as the Catalina or Los Guineos soils, and for this reason the Panama root disease of bananas is not likely to be so severe as on the more acid soils. Minor crops grow well.

Some areas, especially in Barrio Frontón in the municipality of Ciales, have a distinctly brighter reddish-purple color than is typical of this soil, but as crop use is the same, these areas were not separated on the map.

Alonso clay, smooth phase.—Areas of Alonso clay that have a slope of less than 30 percent are classified as Alonso clay, smooth phase. This soil has a purplish-brown friable clay surface soil that readily forms a fine-granular or mellow condition when cultivated. It is underlain, at a depth of about 8 inches, by a firm but friable brownish-purple granular clay subsoil that gradually changes to more friable looser purple clay, which, in turn, rests on porous rock lying, in most places, at a depth of more than 4 feet. In some places the depth to rock is more than 30 feet.

The mechanical analysis of a typical sample of this soil shows that the surface soil contains more than 81 percent of clay and 13 percent of silt, and that most of the remaining 6 percent is fine sand and very fine sand. The subsoil contains more than 91 percent of clay, of which 88 percent is composed of particles of colloidal size. The lower part of the subsoil contains less clay and more silt than the surface soil, but even below a depth of 4 feet, the clay content is more than 79 percent. All layers of this soil have many very fine disconnected tubelike channels that readily allow water to pass, as the character of the clay is such that when it becomes wet it does not swell to the extent of closing the tubelike channels. Such a soil allows water to penetrate rapidly to great depths, consequently the run-off is not great. Very little destructive erosion has taken place on this soil because absorption of water is rapid and the soil has neither a high content of silt, which may melt like sugar under a tropical shower, nor the abrasive effects of tons of sand flowing down the hillsides. In many places erosion barely keeps pace with the rapid decomposition and disintegration of the rocks.

The best areas of this soil probably are the most desirable all-round soils in the uplands (fig. 104). The land is easy to cultivate, does not dry out excessively during droughts, has a rather large water-holding capacity, and has a fairly high content of organic matter.

The average yearly acre yields of crops on this soil are as follows: Coffee, from 400 to 600 pounds an acre; grapefruit, from 400 to 600 boxes; pineapples, about 300 crates; beans, from 200 to 300 pounds; corn, from 10 to 15 bushels; and sugarcane, from 30 to 35 tons. Fertilizer is required for best yields, but this soil will produce better yields without the addition of fertilizer than the Catalina, Cialitos, and related soils. This soil occurs in areas closely associated with the typical soil, and nearly all of the land is planted to some productive

FIGURE 104.—Numerous subsistence crops growing on Alonso clay, smooth phase. The small irregular-shaped fields surrounding the jibaros' homes give the landscape an intricate pattern.

Frutos menores creciendo en Alonso arcilloso, fase lisa. Los campos en forma irregular que rodean las casitas de los jíbaros le dan al panorama un aspecto intricado.

crop. Probably more than 60 percent of it is in coffee, 20 percent in subsistence crops, and the remaining 20 percent about equally divided among sugarcane, pineapples, citrus, and tobacco.

Alonso clay, colluvial phase.—Areas of Alonso clay occurring near the bases of long gentle slopes on narrow strips adjacent to ravines and having a deeper surface soil than either Alonso clay or Alonso clay, smooth phase, are classified as Alonso clay, colluvial phase. As this soil occurs only in sections where the rainfall is high and the elevation above 500 feet, it is used mostly for the production of coffee and subsistence crops. Yields are better than on the typical soil. If properly fertilized, this soil would be as productive as or slightly more productive than Alonso clay, smooth phase, as it has a better surface soil with higher water-holding capacity and, therefore, higher natural productivity. Farmers prefer this soil to the typical soil, but as it is so closely associated with typical Alonso clay, the land use of the two soils is nearly identical.

Alonso clay, shallow phase.—Alonso clay, shallow phase, is the poorest of the Alonso soils. This soil not only is very shallow, but it also is very steep and may have many rocks on the surface. Most of

it occurs on hills having more than 60-percent slopes. Large areas are near Cialitos.

The physical and chemical characteristics of this soil are similar to those of the typical soil, but because it is so shallow it is more droughty, less desirable for deep-rooted crops, and, therefore, is used only for pasture and trees. Grass growing on this soil is considered slightly more desirable than that growing on the red soils of the uplands. The tree growth is about the same as on the Los Guineos soils.

In places where the parent rock is at or near the surface, some areas of this soil appear nearly white. This is true of the areas in the vicinity of Río Bucarabones.

Alonso silty clay loam.—Alonso silty clay loam differs from Alonso clay in that it has a lighter textured surface soil and occurs in areas having an average annual precipitation of about 70 inches. The largest area of this soil is adjacent to and south of Central Pasto Viejo. The total area is less than 400 acres.

This soil is characterized by a purplish-brown friable softly granular permeable silty clay loam surface soil ranging in thickness from 4 to 8 inches, depending on the steepness of the slope. The subsoil is brownish-purple or purple friable permeable massive clay resting on purple igneous rocks at a depth ranging from 18 to 24 inches. The surface soil is acid, and the soil becomes slightly more acid with depth. It occurs on hills with slopes ranging from 20 to 60 percent.

About 50 percent of the land is used for the pasturing of goats and cattle; the other 50 percent is planted to subsistence crops, such as sweetpotatoes, pigeonpeas, corn, beans, yautias, and yuca. The soil is well adapted to such crops, and good yields may be expected if precaution is taken to prevent erosion on the steeper slopes. Brush terraces and hedgelike terraces, made by planting guinea grass in narrow strips with the contours, should be beneficial. Crop yields are higher on this soil than on the associated Sabana soils.

Alonso silty clay loam, colluvial phase.—Areas of Alonso silty clay loam at the bases of the hills and along the concave slopes adjacent to the drainageways are separated as a colluvial phase of the typical soil. This soil has a deeper surface soil, subsoil, and substratum and a higher inherent natural productivity than the typical soil.

The total area does not greatly exceed 100 acres, of which more than 70 acres are in pasture and the remaining 30 acres in sugarcane and minor truck crops. Sugarcane is the most profitable crop that can be grown on this soil, but, as the soil occurs in such small areas, most of it is used for pasture in connection with the larger areas of the typical soil.

Malaya clay.—Areas of Malaya clay are readily identified by their purple color, in contrast to the brown color of the closely associated Múcara soils and the red color of the Río Piedras and Catalina soils.

Malaya clay is characterized by a dark brownish-purple friable granular permeable alkaline clay surface soil ranging from 2 to 10 inches in thickness, depending on the degree of slope. This layer is underlain by grayish-purple loose friable permeable alkaline clay that gradually changes to disintegrated purple vesicular rocks. Many calcite crystals are in the cavities of the rocks. The depth of the soil above the rock varies greatly within short distances. In places the rock is visible on the surface, and in other places it is below a depth of 30 inches. Rocks and rock fragments are strewn over the

surface to such an extent that most cultivation is done by hand. Seams of copper compounds are conspicuous in areas of this soil.

Malaya clay differs from Alonso clay in that it is derived from a volcanic flow or a succession of flows, and in most places it is alkaline or calcareous in the lower part of the subsoil, owing to calcite fillings in cavities and small cracks in the rocks and in the vesicular lava. The larger bodies of this soil occur on hills having from 20- to 60-percent slopes within a wedge-shaped area about 1½ miles south of Aguada. The lava flow must have spread out to the north and west for a distance of about 2 miles covering all the area, as nearly all the soil within this area is purple, with the exception of that on a few small shale hills, which have red clay soil. This area is thickly populated, and the houses are numerous on nearly every hill.

The steepest part of this soil is used mainly for pasture. Subsistence crops occupy the largest acreage of the cultivated crops grown. They do very well considering the small quantity of fertilizer the land receives. Sugarcane yields from 8 to 10 tons an acre, beans about 200 pounds, pigeonpeas 300 pounds, and corn about 300 pounds.

Malaya clay, smooth phase.—Areas of Malaya clay that are nearly level or have smooth relief are classified as Malaya clay, smooth phase. In cultivated fields, the surface soil, to a depth of 8 or 10 inches, consists of purplish-brown softly granular friable permeable clay with more than 60 percent of the particles of colloidal clay size. This soil, when wet, is mellow and works readily into a good seedbed. Large hard clods seldom remain intact for any length of time, as the first or second rain soon slakes them to small angular fragments or rounded soft granules. Nearly every granule has white pinhead specks on it. The subsoil, to a depth of 15 or 18 inches, contains less organic matter and is more compact than the surface soil. It ranges in color from purple to brownish purple and breaks into various-sized clods that feel slightly plastic when wet. Internal drainage, however, is good, and plant roots penetrate the soil readily. The upper part of the subsoil gradually changes to a lower lying layer of nearly the same texture and color, but the material is more friable. This layer continues below a depth of 10 feet before rock is reached.

In most places this soil is acid in all layers, but where it is adjacent to the typical soil it is neutral or alkaline. A few rocks lying on the surface are calcareous. Rocks are not so numerous as on the typical soil. This soil has only normal erosion, and very little water is lost through run-off, especially in places where the land is in crops or grass. In most places the slopes to the drainageways are gradual, and very few of the drains are V-shaped.

Nearly all of this soil could be cultivated profitably to sugarcane, coffee, pineapples, or many of the minor crops. In 1929 the two most important crops growing on this soil were sugarcane and beans. The sugarcane produced from 20 to 22 tons to the acre without fertilizer, beans about 700 pounds, sweetpotatoes 4,000 pounds, ñames 6,000 pounds, yuca 1,500 pounds, pigeonpeas 400 pounds, coffee 200 to 300 pounds, and corn 800 pounds.

This soil is considered nearly twice as valuable as the typical soil and has about the same value as Alonso clay, smooth phase.

Jayuya silty clay loam.—Jayuya silty clay loam occurs within the upland areas of the large granite area near Utuado and Jayuya, in those exceptional places where the relief is smooth and the mean annual

rainfall is sufficient for the soil-forming processes to produce a red soil.

This soil has a total area of only a few square miles, and it occurs only on the nearly level hilltops and the low rounded hills within areas of soils derived from granite and receiving from 80 to 100 inches of average annual rainfall.

In cultivated fields the 6- or 8-inch surface soil is brown or grayish-brown slightly plastic acid silty clay loam containing some gritty material. The subsoil to a depth of about 2 feet is medium-stiff red massive acid sandy clay or sandy clay loam, which gradually changes to friable red coarse-grained sandy clay loam or sandy loam. The parent material, lying at a depth ranging from 30 to 40 inches, is gritty quartz sand. The material in all layers is acid, and, because of the nature of the parent material, internal drainage is not restricted and does not interfere with crop production or cause a mottled condition in the subsoil.

This soil is not nearly so high in colloidal clay as the other soils in this group, but because it occurs within the same rainfall area and has a red color it is in the same group. It contains some gritty sandy material, and it erodes more seriously than the other permeable red and purple clay soils in the group. Many brush terraces are maintained throughout the fields of this soil.

Probably about 40 percent of the land is planted to coffee; 30 percent is in tobacco, beans, and corn; and 30 percent is in pasture and trees. Evidence of lack of nitrogen is not so noticeable in this soil as in the other soils derived from granite, but this soil requires large quantities of fertilizer high in nitrogen for the profitable production of most crops. Under favorable climatic conditions and good management the soil produces an average acre yield of about 100 pounds of coffee, 800 pounds of tobacco, 200 pounds of beans, or 15 bushels of corn. At least 2 acres of grassland are required to pasture a cow.

Jayuya silty clay loam, steep phase.—Areas of Jayuya silty clay loam that have a steep relief are designated on the map as a steep phase. This soil is slightly inferior to the typical soil for the production of cultivated crops, as the surface soil is shallower, owing partly to erosion and partly to less development of soil on the steep relief. The yield of coffee on a well-managed coffee farm on this soil is about the same as the yield on the typical soil. The unevenness and steepness of the relief is an objection in the cultivation of the land. A large proportion of the land is in coffee, especially the rougher parts, but the more favorable areas are used for the production of sugarcane, tobacco, and corn. Most crops produce less on this steep soil than on the typical soil.

Bodies of this soil are scattered throughout all areas of soil derived from granite in the vicinity of Utuado and Jayuya. This soil is more extensive than the typical soil. A large area surrounding Central Pellejas (see fig. 145, p. 483) is planted almost entirely to sugarcane which yields about 28 tons to the acre.

Nipe clay.—Nipe clay is easily identified because even when dry it stains clothing and flesh a purplish-red color. Buildings on this soil are stained red, especially the lower parts. The feet of horses and people treading across the land are stained with purplish-red colloidal clay.

Nipe clay is not only the most unproductive soil in this group, but it is one of the most unproductive soils in Puerto Rico, as well as in Cuba, where it occupies large mountainous areas. The largest areas in Puerto Rico are in the vicinity of Mayagüez, where the average annual rainfall is in excess of 80 inches. The relief of all areas of this soil is favorable for cultivation, as the soil occurs on high rounded hills and in flat tablelike positions. This soil is derived from serpentine rock.

The 5-inch surface soil of Nipe clay is dark brownish-red softly granular very slightly plastic neutral or slightly acid clay. The brown color is due almost entirely to organic matter, for the granules when crushed become very much lighter red. This material, although low in organic matter, contains from five to eight times the amount in the lower layers. Apparently owing to the presence of organic matter, this layer has a higher water-holding capacity than the layers below. A distinct boundary occurs between the surface soil and the subsoil, which consists of purplish-red nonplastic neutral clay composed of very small soft granules that crush readily to a fine mulch. This layer ranges from 15 to 20 inches in thickness. The material gradually changes to purplish-red loose friable soft and fairly granular nonplastic clay that continues to the serpentine rock, which, in places, lies at a depth of more than 30 feet. This soil, with the exception of the topmost few inches, has a dead appearance, and it feels more like a chemical compound than like a soil.

This soil has a number of characteristics peculiar to certain tropical soils called lateritic soils or Laterites. Very little change is noted in the physical properties from the surface to the underlying rock. The soil in all layers contains more than 71 percent of clay, in most of which the particles are of colloidal size. The clay particles are grouped in clusters and do not have the plastic nature of most clay but exhibit the physical properties of loam. Although water penetrates the soil rapidly, it is not retained so well as in most clay soils. This soil, when wet, is sticky and slippery, but it dries very quickly, and cultivation is seldom delayed for any great length of time after a rain. The soil, if worked when wet and the large clods turned over, slakes to small crumblike particles after the first or second rain.

As observed in a roadside cut, the soil shows little evidence of swelling or contracting at the extremes of moisture content. It dries to a great depth during long dry periods, however, and is considered more droughty than soils derived from shale or limestone. The native vegetation is typical of areas receiving much less rainfall. When the vegetation is removed and the land is idle, grasses and trees grow so slowly that it takes years to form a complete cover. Thus the soil is exposed to sheet erosion which becomes rather severe on this naturally nonerosive soil. The effect of the hot sun on the bare soil also is destructive, as the heat burns the organic matter in the soil and causes the material in the surface layer to become very hard, in places forming a firm crust. When cultivated, this layer is readily broken up.

Chemical analyses of this soil show that the silicon dioxide decreases and the aluminum oxide and iron oxide increase with depth to the serpentine rock. The content of phosphorus is very low, and that of potash is below the average for productive soils. The content of chromium and nickel is high, and possibly these substances have a

toxic effect on plant roots, thereby preventing normal growth. This soil has a higher content of iron than any other soil in Puerto Rico. Some layers contain more than 50 percent of iron oxide. In most of the layers, small black iron pellets, concretions, or perdigón are conspicuous, and in some places ironstones ranging from 2 inches to 3 feet in diameter are embedded in the soil at a depth of about 8 inches, unless erosion has washed the surface soil away, thus exposing the ironstones as well as thousands of smaller iron concretions.

This soil is used principally as grazing land. The grass produced is coarse, tough, and of little nutritive value. The most important grasses aré matojo, burro, cerrillo, rabo de ratón, cortadera, and carrucillo. Many ferns grow luxuriantly, but such trees as mango, mamey, and capá grow only fairly well. Mahogany and cedar grow slowly. Coffee trees grow fairly well on the concave slopes that receive an additional supply of moisture and organic matter from the surface wash of the adjacent slopes. Pigeonpeas and onions are two of the best minor crops now growing on this soil, since they withstand drought well and thrive in soils that are not too acid. One patch of onions on this soil produces from 7,000 to 10,000 pounds to the acre when fertilized with from 600 to 800 pounds of fertilizer an acre and when sufficient lime is applied to make the soil alkaline in reaction. The onions are planted in August or October. Pigeonpeas yield from 100 to 250 pounds to the acre.

Potatoes and corn are fairly well adapted to this soil, but yields are very low unless heavy applications of fertilizer high in phosphorus and potash are applied, in addition to large quantities of lime. The yield of sugarcane is very low, often not more than 15 or 20 tons, even with the use of fertilizer. The fields planted to sugarcane include many barren spots, ranging from 20 to 100 feet in diameter, where the sugarcane germinated but never attained full growth and in many places died.

This soil, although very high in content of clay, is well drained and should be suitable for poultry yards. Guinea grass will grow fairly well and would be much more nutritious than the grass now grown. This land is sparsely populated, and only comparatively few livestock graze on the wind-swept mesas or tablelands. Probably 80 percent of the land is idle or in poor pasture. Most of the other 20 percent is in sugarcane. Ultimately, it doubtless will be used as a source of iron ore, when richer deposits of iron in other parts of the world have been exhausted.

MEDIUM-DEEP SOILS OF THE UPLANDS

The medium-deep soils of the uplands include the hilly lands of the humid and subhumid sections, that have parent rock at a depth ranging from 1 to 2 feet below the surface.

Owing to the rather steep relief and thinness of the soil, the soils in this group are naturally better adapted for shallow-rooted crops, such as tobacco and subsistence crops, than for sugarcane and citrus. Some sugarcane is grown on the best parts of the land adjacent to main roads and near sugar centrals. Nearly all of the best-quality tobacco, most of the upland rice, and probably 60 percent of all the subsistence crops are produced on the soils of this group. The subsistence crops are mainly beans, corn, pigeonpeas, and sweetpotatoes. Probably a greater number of farmers derive either all or a part of

their income from these soils than from the soils of any other group. The success or failure of many thousands of people depends on the productivity of these soils (fig. 105).

The value of these soils depends on the degree of slope, the amount of surface soil lost by sheet erosion, and, to some extent, the number of years the land has been producing clean-cultivated crops without the addition of much fertilizer.

The requirements for successful management of farms on these soils are: The use of fertilizers, sound practices for the control of erosion, diversification of crops, and the raising of large numbers of livestock.

The soils in this group include 39 soil types and phases of 16 soil series. The Colinas, Soller, and Tanamá soils are derived from Tertiary limestone; the Plata soils, from lower Tertiary clay; the Daguao, Múcara, Juncos, Sabana, and Naranjito soils, mostly from massive

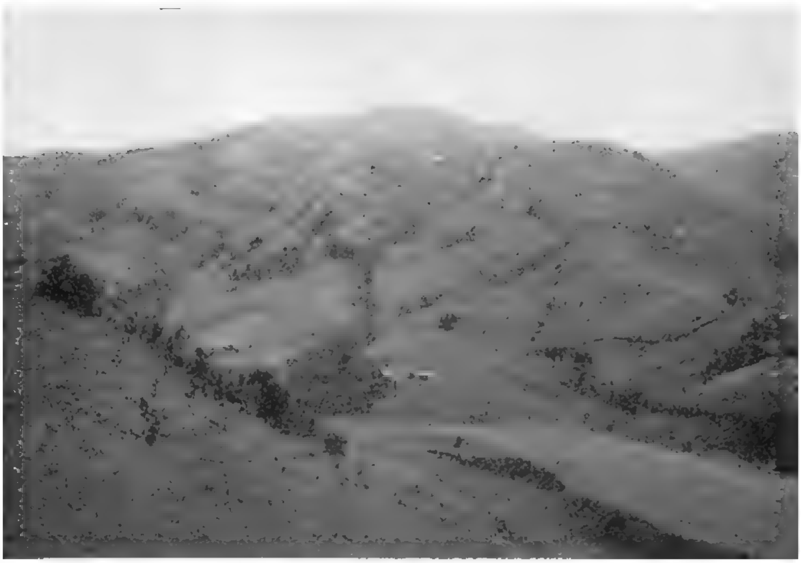

FIGURE 105.—The success or failure of many thousands of people in Puerto Rico depends on the productivity of the medium-deep soils of the uplands, such as this area of Múcara silty clay loam. Erosion is slight on ordinary slopes of 15 or 20 percent, owing to the rapid growth of plants. On slopes in excess of 40 percent, however, erosion is a factor that needs serious consideration.

El éxito o el fracaso de muchos miles de personas depende de la productividad de los suelos medianamente profundos de la altura, tales como esta área de Múcara limo-arcilloso lómico. La erosión es leve en declives de 15 a 20 por ciento debido al rápido crecimiento de las plantas. En laderas de más de 40 por ciento, sin embargo, la erosión es un factor importante.

tuffs, tuffaceous shales, and other volcanic rocks; the Río Piedras soils, from shale; and the Pandura, Cayaguá, Ciales, Utuado, Teja, and Vieques soils, from igneous rocks, mostly granite.

To facilitate the description of the soils in this group, those derived from the same or similar parent material will be discussed together.

Colinas clay loam, Colinas stony loam, Colinas fine sandy loam, and Soller clay are derived from soft or medium-soft limestone, and they are calcareous at a depth averaging about 20 inches. Soils of

some hilltops are calcareous at the surface. The best of these soils are the most productive soils in this group for sugarcane, and most of their area adjacent to the main roads is used for this crop. Soller clay is the best, and ranking with it are the best areas of Colinas clay loam. Sugarcane grown on these rolling or steep hills yields from 35 to 40 tons an acre gran cultura and from 20 to 35 tons in ratoon crops. It is not uncommon to grow six ratoon crops on these soils. In general the sucrose content in the cane grown on these soils is high, and very few of the cane stocks have suckers as is common on the wet alluvial lands. The main sugarcane variety grown is S. C. 12/4, but it is rapidly being replaced by P. O. J. 2878 and P. O. J. 2725, as the cost of cultivation is greater for S. C. 12/4 and it is more susceptible to mosaic disease than the P. O. J. canes mentioned. P. O. J. 2878 is a shallow-rooted cane, but when planted in these dense plastic clays and clay loams it does not uproot so readily as it does in the wet alluvial soils. Even when it does blow over, the soil is seldom wet enough for the nodes to germinate, start growing, and cause a loss of sucrose. Uba cane produces fairly well but is not recommended, as it is hard to cut and to grind. Mayagüez 28 appears promising for the most of the hill lands, as it can withstand drought well and closes in quickly, thereby reducing the number of cultivations necessary to kill the weeds. It is also a very prolific stooler. The fertilizer generally used on this land is 400 pounds to the acre of 12–6–8 at the first application and 400 pounds of ammonium sulfate at the second application.

Probably a larger area of these soils is in pasture than in sugarcane, but, because of the value of sugarcane, their use for pasture rates second in importance. Most of the permanent pasture land is covered with a thick stand of a mixture of fine-leaved cerrillo grass and a broad-leaved grama grass. Nearly all areas are free from weeds. From 1½ to 3 acres of land are needed to pasture an animal a year. The usual charges for pasturing animals is $1.50 a head a month. At this rate the yearly income would be from $6 to $12 an acre if the land were pastured the entire year, which is not unusual. The pasture land sells at prices ranging from $25 to $40 an acre. Grass grows better on the soils derived from limestone than on the soils derived from shale and tuff, provided they have the same rainfall.

Sweetpotatoes, pigeonpeas, corn, beans, and yautias are the main subsistence crops grown on these soils. The acre yields of the various crops are as follows: From 800 to 1,200 pounds of sweetpotatoes, from 300 to 600 pounds of pigeonpeas, about 10 bushels of corn, from 350 to 450 pounds of beans, and from 1,000 to 1,500 pounds of yautias.

In places where these soils are planted to crops requiring frequent cultivation, the surface soil erodes at a much more alarming rate than is realized by most landowners. It is true that these soils are now producing much higher yields, especially of sugarcane, than they did several years ago, although they have been in continuous cultivation. The increase is due to the selection of better varieties of sugarcane, better rate of planting, and better fertilization. Erosion starts on the top of the hill and gradually continues down the slope. The good original black surface soil is gradually being washed down the hill by sheet erosion. It is true that for some time the slopes gradually will produce better yields, but they are doing it at the expense of the soils farther up the hill, which are producing less and less as their surface

soil is removed by erosion. Near the top of the hill the surface soil is lacking in many areas, the subsoil is very thin, and, in places, the bare gray limestone is exposed. The sugarcane growing on these lime spots sometimes is affected with chlorosis. It is impossible for this thin soil resting on limestone to produce as much as the lower slopes that have a black surface layer more than 8 inches thick overlying a yellowish-brown plastic equally thick subsoil. When fertilized, these lime-exposed hilltops produce remarkably well, due to the friability of the soft limestone which allows the sugarcane roots to penetrate deeply. These soils produce even higher yields than the less eroded slopes of the Múcara and Río Piedras soils. If erosion is allowed to continue without check, in time the soil on the hills may become so thin that the land will be adapted only for pasture. Some of the steeper slopes of Soller clay already have been rendered nearly worthless by sheet erosion, owing to improper farm practices. Some erosion has taken place in the overgrazed pasture lands, but not nearly so much as in the sugarcane lands, and sugarcane lands are not nearly so eroded as lands used for the production of subsistence crops, especially pigeonpeas, beans, and corn. Strip crops, and plowing and planting with the contour, would help greatly to prevent erosion in these soils that have such plastic consistence that they absorb water slowly, making the run-off high.

These soils have an undulating or rolling relief and occur throughout the northwestern part of the island, extending from the coast to a distance of more than 8 miles inland. The elevation in this section ranges from sea level to 700 feet above, and the average annual rainfall ranges from about 50 inches near Isabela to more than 95 inches near San Sebastián. Most soils receiving from 70 to more than 90 inches of annual precipitation would be seriously leached of their plant nutrients, but as these soils are young and derived from soft limestone, the rainfall has very little leaching effect. In these soils the higher the rainfall the darker the soil and the higher the organic content. The quality and kind of grass vegetation changes but little throughout areas of these soils, but the quantity is much less in the drier areas than it is in the humid areas.

The drainageways in these soils are short, indefinite, and for the most part lead to subterranean channels. Only a very few streams cross areas of these soils, and water for domestic purposes is scarce, inadequate, and in many places far from the numerous houses that dot the hills. Some rain water is caught from the galvanized roofs of the houses.

The Tanamá soils are derived from a medium-hard Tertiary limestone that weathers so slowly that the soil produced is red, thin, permeable, and acid. Most of the two Tanamá soils included in this group are farmed by small landowners who plant coffee, bananas, tobacco, and subsistence crops. Yields are generally low, and a considerable acreage of these soils is adapted only for forestry, owing to prevalence of sinkholes and rock outcrops.

Although Plata clay and its mixed phase are closely associated with the shallow soils derived from limestone, they are derived from older materials and will be discussed separately.

The soils of the Daguao, Múcara, Juncos, Sabana, and Naranjito series are closely related. They have been derived from similar parent material, have about the same depth to unconsolidated rock, and are

adapted to about the same kinds of crops. They range in color from black to light grayish brown and in acidity from alkaline to strongly acid. Beginning with the Daguao soils, which are the most alkaline and darkest, the soils become less dark and more acid in the following order: Múcara, Juncos, Sabana, and Naranjito. The Daguao soils receive the least rainfall and the Naranjito soils the most, so, generally speaking, with increasing amounts of soil water the soils become more acid and more gray.

The soils occur in the subhumid part of the island between and east of the north and south limestone belts. The steep phases of these soils are included in the group of shallow soils of the uplands and are used predominantly for pasture, but the soils in this group are used extensively for tobacco, subsistence crops, and sugarcane. Where these soils are within a mile of a main-traveled road and not over 4 miles from a sugar central, a larger acreage of their area is planted to sugarcane than to all other crops (fig. 106).

FIGURE 106.—Sugarcane growing on fairly shallow soils with steep slopes, within a mile of a main-traveled road in the western part of the island.

Caña creciendo en suelos regularmente poco profundos en laderas escarpadas, alrededor de una milla de distancia de una carretera principal en la parte oeste de la isla.

If the land is owned or managed by centrals, yields of sugarcane range from 25 to 35 tons to the acre, as the centrals properly weed and fertilize the land and also plant good varieties of cane. If the land is owned and managed by small landowners, however, the sugarcane seldom yields over 20 tons an acre and may yield as low as 12 tons, because the small landowners do not have the capital to buy fertilizer and properly manage this shallow land. Field observations indicate that under present conditions, with 3-cent sugar, this land should produce more than 12 or 15 tons of sugarcane to the acre, in order to return a profit to the owner. These soils are shallow to rock, and it is unreasonable to expect that the sugarcane roots will have sufficient room to secure enough plant nutrients and water for a high yield. Sugarcane roots, unlike tree roots, are unable to penetrate the rock

and, therefore, suffer for water during dry periods. On the Juncos soils and near the bases of the hills of the other soils, the depth to rock is much greater, and yields are noticeably higher.

Tobacco and most subsistence crops do not necessarily require deep soils for profitable production, therefore large acreages of the soils in this group are planted to these crops.

One of the most noticeable practices in farming these soils, especially for tobacco, is the digging of shallow narrow gridiron-shaped ditches (fig. 51) on the hillsides, regardless of the steepness of the slope. The bottoms of many ditches rest on solid rock, thus eliminating conditions favorable for a gully type of erosion. If any soil reaches the ditches, it is washed away, but, by having many small 20- or 30-foot squares surrounded by ditches, the water does not have a chance to collect much soil before it runs into a ditch. These ditches not only reduce erosion but they help drain the soil, making a more favorable growing condition for the tobacco plants.

The Río Piedras soils are developed from rocks of volcanic origin, largely tuffaceous shales, and they occur on hill slopes and ridges. Under weathering in a tropical climate, the rocks rapidly disintegrate forming soils with heavy clay textures.

The Pandura, Cayaguá, Ciales, Utuado, Teja, and Vieques soils are derived from granitic material and therefore have many characteristics in common. All are light colored, gritty, well drained, medium shallow, and susceptible to sheet erosion, and most of them are acid, coarse textured, and low in plant nutrients, especially nitrogen, but they are used extensively for crops, unless cultivation is impossible owing to the high content of rocks and boulders. Tobacco is the most important crop grown, followed in importance and acreage by such subsistence crops as beans, corn, and sweetpotatoes.

These soils occur on hills that range in elevation from 500 to more than 1,500 feet above sea level. The average annual rainfall ranges from less than 40 inches on the Vieques soils to more than 90 inches on some areas of the Pandura, Cayaguá, Ciales, and Utuado soils. The Teja soil receives about 70 inches of average annual rainfall.

The Cayaguá soils are the most productive, followed by the Utuado, Ciales, Vieques, Pandura, and Teja soils. The steeper the relief the less desirable is the soil and the more likely it is to be injured by sheet erosion.

These soils are the most seriously eroded soils from a topographic point of view. They are completely dissected with drainageways. Most of the drains are U-shaped and have a rather deep layer of sand, coarse sand, and fine gravel in the bottom.

The quality of the water throughout areas of these soils is good, but the quantity is not so great as in comparable areas of the Catalina and associated soils or of the Múcara and associated soils.

Colinas clay loam.—Colinas clay loam is easily recognized by two outstanding characteristics. It occurs on low rolling round-topped soft limestone hills (fig. 107), and it has a dark grayish-brown surface soil with many eroded spots exposing the white lime. It is fairly well distributed from the northwestern corner of the island to a point east of Toa Alta, a distance of about 51 miles. It is adequately drained because of its rolling relief.

The 4- to 7-inch surface soil ranges from grayish-brown to very dark grayish-brown granular clay loam. It is underlain by yellowish-

FIGURE 107.—Typical view of Colinas clay loam. These rolling round-topped hills receive about 80 inches of average annual rainfall, and erosion is rather severe on these plastic granular alkaline soils when the land is planted to clean-cultivated crops, such as beans, corn, and pigeonpeas.

Vista típica de un Colinas arcilloso lómico. Estas colinas de cima redonda reciben como 80 pulgadas de lluvia anualmente; la erosión es bastante fuerte en estos suelos alcalinos, plásticos y granulares, cuando se siembran de cultivos como habichuelas, maíz y gandules.

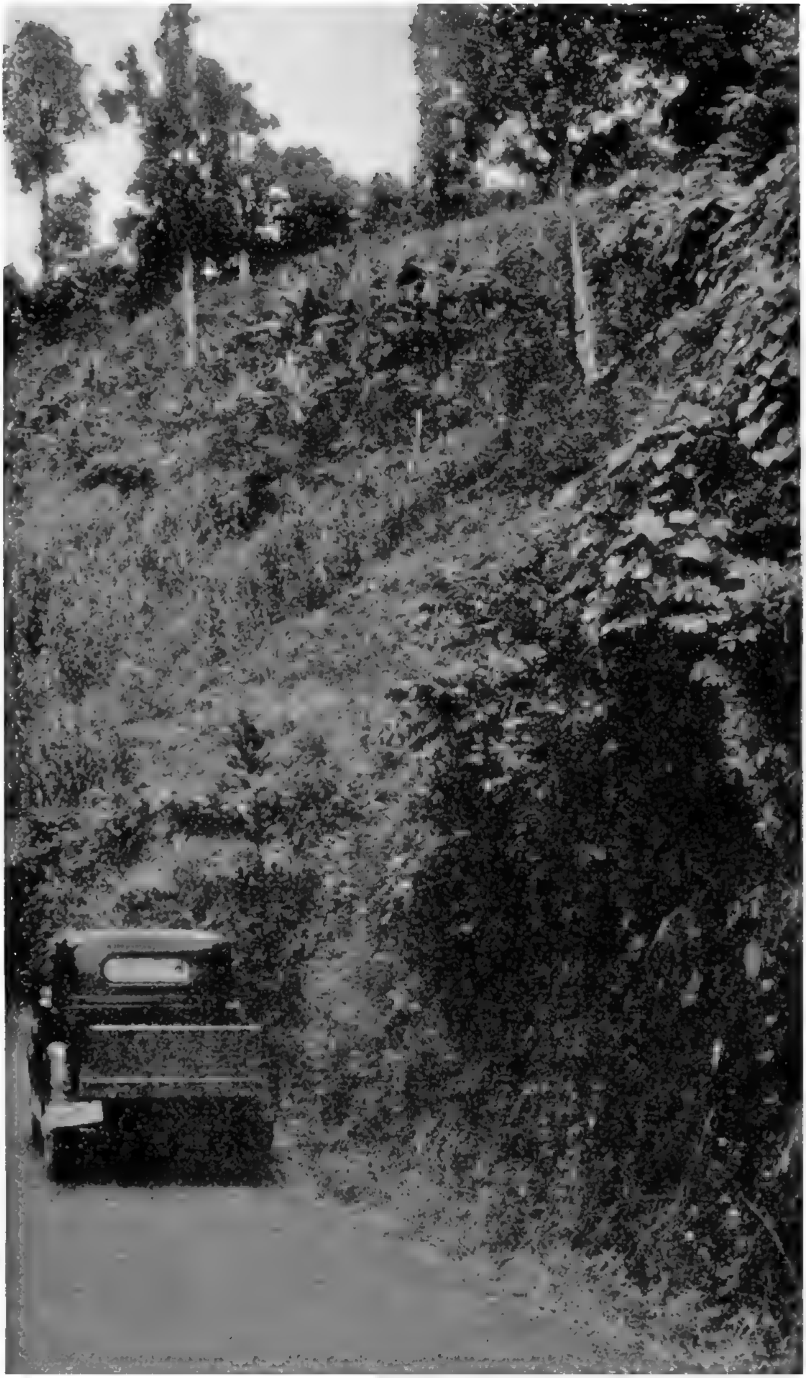

FIGURE 108.—See legend on page 209.

brown or light yellowish-brown clay loam which is slightly heavier and more plastic than the surface soil. This layer grades, at a depth of 12 or 14 inches, into light-gray soft limestone. The limestone becomes harder with depth, but in most places an auger can penetrate it to a depth of 20 inches. Plant roots, however, penetrate to much lower depths for a supply of moisture. This soil is alkaline from the surface downward, and in most places it is calcareous at a depth of 7 inches. In places it is calcareous at the surface, but such areas have been eroded and are distinctly noticeable on account of their light-gray color. They occur on top of the hills or ridges and on slightly higher irregular humps on the hillsides. These spots are not so noticeable if the land has always been in pasture.

Because of surface wash this soil gradually changes toward the base of the hill to deeper and better soils, such as Santa Clara clay and Camagüey silty clay, depending on the extent to which erosion has taken place. The boundary lines between any of these soils are changing gradually.

Nearly all of the land is cleared. About 50 percent of it is in sugarcane, 35 percent in pasture, and 15 percent in such subsistence crops as pigeonpeas, sweetpotatoes, beans, corn, and yautias (fig. 108). The yields produced are about the average for soils of this group.

Colinas stony loam.—Colinas stony loam occurs near the seacoast and probably has been influenced to some extent by the sands blowing from the beach. It has a very dark grayish-brown or black granular loam surface soil from 6 to 12 inches thick, underlain by a layer of grayish-brown loam or clay loam about 4 or 6 inches thick. This material grades into soft gritty limestone at an average depth of 14 inches. The soil material contains an abundance of small limestone fragments throughout. In places this soil may have only a 6-inch soil covering over medium-hard limestone rock. In other places, especially near Islote, the surface soil is slightly darker and more plastic than the average areas of this soil, and in this respect the Colinas soil resembles the Camagüey soils.

The better areas of Colinas stony loam are used for cultivated crops, especially tobacco in the Isabela-Camuy districts and sugarcane in the Islote district. Such minor crops as sweetpotatoes, corn, beans, and pigeonpeas are grown very successfully in all areas, with yields higher than the average for soils of this group. The more shallow areas are used for pasture, especially from Hatillo eastward. The pasture grass is good, but many fields are infested with weeds. This is uncommon for the soils of this group.

Colinas fine sandy loam.—Colinas fine sandy loam is easily distinguished from Colinas stony loam, as it is derived from a much sandier limestone and is, therefore, more sandy throughout. It occurs mainly in a few small areas, but a fairly large area is about 6 kilometers north of Morovis.

FIGURE 108.—Subsistence crops growing on Colinas clay loam having a slope of more than 60 percent. The crops are yautias, corn, and bananas.

Frutos menores o cultivos de subsistencia sembrados en Colinas arcilloso lómico con un declive de más de 60 por ciento. Los cultivos son yautías, maíz y guineos.

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This soil has a dark grayish-brown loose granular fine sandy loam or loam surface soil that gradually changes at a depth of about 5 inches to light yellowish-gray plastic sandy clay loam. In most places this layer is very thin and in some places may be lacking. When present it rests on fairly loose gritty gray limestone.

Agriculturally this soil is less valuable than Colinas clay loam, the soil it most closely resembles. The fine sandy loam occurs chiefly on rolling or steep hills, although a few small areas of colluvial soil or soil in valleylike positions have been included. The total area is only 1,280 acres. The land is used chiefly for pasture and to less extent for subsistence crops. Yields are similar to those obtained on Colinas clay loam. The better areas, especially those that are valley-like, produce fair sugarcane.

Soller clay.—Soller clay, which occurs on the low rolling or undulating hills in the vicinity of Central Soller, is the best soil of the Soller series. It has a very dark grayish-brown or black plastic dense granular clay surface soil from 4 to 7 inches thick, which, when dry, breaks into dense hard clods that require several rains in order to slake into fine granular particles. The subsoil is grayish-brown plastic clay that gradually changes to white loose calcareous marl of clay loam texture. In most places the marl occurs at a depth of 12 inches or less. In places, erosion has caused the marl rock to be exposed, thus reducing the value of the land from about $65 to $20 an acre or even less. Drainage is adequate, as the slope is sufficient to drain off excess water.

Road banks show that this soil contracts and expands greatly at the extremes of moisture content, as fairly wide cracks extend from a depth of 10 or 12 inches to the surface of the ground. In cultivated fields, cracks 1 or 2 inches wide may appear during dry periods following heavy rains. The soil is used almost entirely for the production of sugarcane, average acre yields of which are about 45 tons gran cultura.

Tanamá stony clay, smooth phase.—Tanamá stony clay, smooth phase, is an extensive soil derived from hard Tertiary limestone. It occurs in small limestone valleys throughout the north-coast limestone belt in less hilly areas than typical Tanamá stony clay. This soil is nonirrigable and is a very poor agricultural soil. The 4- to 8-inch surface soil consists of reddish-yellow or reddish-brown granular stony clay, and the subsoil is reddish-yellow or brick-red clay grading into hard limestone rock at a depth ranging from 8 to 30 inches. The average thickness of the profile to bedrock is probably about 15 inches. In places, the soil is not deep enough to develop a subsoil. It consists of brownish-red clay about 8 inches thick overlying loose small hard and soft limestone rocks. Numerous fragments of limestone are distributed throughout the soil, and limestone outcrops are fairly numerous (fig. 9).

Nearly all of this soil has been under cultivation at some time, but now a large proportion of it is in pasture. The principal crops grown are the shallow-rooted ones, such as onions, beans, sweetpotatoes, and tobacco. Tobacco, however, is grown only where the soil is more than 10 inches deep. In a few places sugarcane and coffee are grown fairly successfully. In dry seasons all crop yields are low, but during favorable years, yields are fair, about the same as on Colinas clay loam. Most farms on this soil range in size from 7 to 10 acres.

The income from the farm usually is insufficient for the owners to make a living, so they must obtain part-time work elsewhere. Owing to the shallowness and rockiness of the soil almost all of the field work must be done by hand, and if the land is plowed wooden plows are used to the best advantage. The surface soil is alkaline or slightly acid in reaction, and the subsoil in most places is acid.

Tanamá stony clay, colluvial phase.—Tanamá stony clay, colluvial phase, is a complex of the materials on the colluvial slopes of hills occupied by Tanamá stony clay and the material in the small irregular-shaped limestone valleys, sinks, and basins. The size of most areas of this complex ranges from 1 to 30 acres. The soils in the valleys may be any one of the soils derived from Tertiary limestone, but, as these valleys are so small and inaccessible, and no differentiation is made in their crop use, all are classified with Tanamá stony clay, colluvial phase.

Most of the soil is farmed by small landowners who plant coffee, bananas, tobacco, and subsistence crops in the valleys. Many of the sinks and small basins are used only for forestry, and the colluvial slopes produce only brush and trees. Most of this soil is so inaccessible and occurs in such small narrow strips that it adds very little to the value of the surrounding poor-quality Tanamá stony clay. Coffee is well protected from hurricanes in the small valleys. Since any material that is washed from the adjacent hills collects in the valleys, the soils in the lowest parts of the basins or valleys are much higher in organic matter than the surrounding soils.

This soil is about uniformly distributed throughout all areas of Tanamá stony clay, but on the soil map the areas between Ciales and Río Guajataca appear much more numerous than in other parts of the limestone section. This is because these areas include a larger proportion of slopes of Tanamá stony clay than is included in the other areas.

Plata clay.—Plata clay is derived from gravels and clays lying beneath the Tertiary limestone and therefore occurs on rolling rounded hills just south of the north-coast limestone escarpment and north of the south-coast limestone hills.

It is characterized by a grayish-brown or dark grayish-brown friable neutral clay surface soil 6 or 8 inches thick, containing many rounded quartz pebbles. The subsoil is yellowish-brown friable neutral clay loam containing much disintegrated gravel. At an average depth of 17 inches the material is firm but friable silt loam, neutral or alkaline in reaction and containing much gravel. This material continues to a great depth. In places, it is stratified with layers containing a large quantity of partly rounded rocks and rock fragments. In some places the soil is slightly mottled with gray and yellowish brown at a depth ranging from 6 to 17 inches.

About 50 percent of this soil is in grass, 30 percent in sugarcane, and the remainder in minor crops and coffee. The soil is considered superior to Múcara silty clay loam and about as good as Juncos clay.

Areas of this soil that have a considerable quantity of pebbles on the surface and throughout the profile are shown on the map with gravel symbols. These areas are more rolling, not so heavy, and lie nearer to the streams than the typical areas, and many of them are planted to sugarcane, which yields slightly better than on the typical areas.

Plata clay, mixed phase.—Plata clay, mixed phase, is readily identified by its variegated color. It occurs on steep slopes just south of the limestone escarpment, from Moca to Corozal, associated with the Colinas and Soller soils.

The 6- or 8-inch surface soil ranges from grayish-brown to black plastic waxy clay. It is underlain by plastic sticky clay having a peculiar banded mottled assortment of bright colors, mostly red, purple, gray, and brown. At a depth ranging from 30 to 40 inches, the material is about the same as that underlying typical Plata clay. In some places, lime carbonate occurs throughout the profile, owing to seepage of lime from the higher lying adjacent limestone soils. In most places this soil slopes toward the south, is well drained, and occurs in long narrow strips or small irregular-shaped areas, which are used for pasture, corn, and coffee. Crops grow very well, but because of its unfavorable relief more than 70 percent of the land is in pasture. The carrying capacity of the pastures is about 1½ acres for an animal a year. The rainfall is sufficient for nearly continuous plant growth.

Daguao clay.—Daguao clay is similar to some of the southern Prairie soils of the United States. It is a shallow nearly black soil of the uplands developed on rolling or hilly relief and derived from andesitic rocks having a green tinge. It occurs only in areas where the mean annual rainfall is between 55 and 65 inches. Most of it is in the eastern part of the island near Ensenada Honda.

The 6-inch surface soil when wet is nearly black granular plastic clay, but it becomes hard and cloddy when dry. Cracks 2 inches wide are common in dry fields. The upper part of the subsoil is reddish brown or brownish red, plastic when wet, and hard and dense when dry. The lower part of the subsoil is mottled brown and dark-gray plastic sticky clay resting on partly disintegrated rock at a depth ranging from 20 to 30 inches, depending on the degree of slope and the extent to which sheet erosion has taken place. On some of the steepest slopes, the disintegrated parent rock lies within 3 inches of the surface. The material in all layers is neutral or alkaline in reaction.

Nearly all of this soil has been used at some time for the production of sugarcane, which yields from 20 to 35 tons an acre during favorable years but less than 10 tons during dry years. Experience has shown that, under present conditions, owing to the frequent dry years, this soil is more productive for grass than for sugarcane. The grass produced is of very good quality, especially in areas that have been in grass for many years. At present, more than 50 percent of the land is used for pasture, the carrying capacity of which is about one animal to the acre during most of the year.

In places large boulders and rock outcrops are very conspicuous, and they reduce the value of the land.

Daguao clay, colluvial phase.—Areas of Daguao clay occurring at the bases of the hills and having much deeper surface soils and subsoils than typical are mapped as Daguao clay, colluvial phase. Agriculturally this soil differs from the typical soil in that it is better adapted to sugarcane and produces much higher yields year after year. It is very similar to Mabí clay, but it is slightly more alkaline in reaction and the subsoil is more reddish brown.

The soil occupies a very small area in the eastern part of the island. Probably 50 percent of the land is used for the production of sugarcane and the remainder for pasture.

Daguao clay, colluvial phase, is valued considerably higher than the typical soil, but it is more difficult to plow and prepare for sugarcane.

Múcara silty clay loam.—Múcara silty clay loam is the most extensive and most widely distributed soil in Puerto Rico. It occurs in nearly every part of the upland where the mean annual rainfall exceeds 65 inches. This soil is easily recognized by its dark-brown surface soil and light-brown shallow subsoil overlying tuffaceous rocks. In a well-managed cultivated field the surface soil is dark brownish-gray or grayish-brown medium plastic silty clay with a rather distinct crumb structure. This layer is underlain at a depth of about 8 inches by yellowish-brown or light-brown plastic clay or silty clay having a tendency to become mottled gray and yellowish gray in the lower part. In places, small angular fragments of partly weathered rocks are abundant in this layer. They become more abundant with depth. The depth to rock, as well as the thickness of each layer, depends on the slope. This soil occurs on hills having slopes ranging from 30 to 60 percent, and near the tops of the steeper hills the entire thickness above the rock is in few places more than 14 inches and in many places is less than 8 inches. In such localities, all layers are thin. Near the bases of the hills, or in places where this soil grades into Juncos clay, the parent rock may be nearly 3 feet below the surface. Throughout all layers of this soil, white hard specks are conspicuous, indicating that not all the minerals have become decomposed and therefore the soil has more or less of a reservoir of plant nutrients that are gradually released and made available to the plants. This soil is neutral or slightly acid in the surface soil and becomes more alkaline with depth. In some places, free lime carbonates occur in the rock seams. Here and there boulders and rock outcrops occur on the ridge tops and the steeper slopes.

Múcara silty clay loam is a well-drained soil, owing to the steepness of its relief. In small areas at the heads of drainageways and in a few small areas on flat ridge tops, however, drainage is inadequate for the production of good-quality tobacco. Such areas are spoken of as cold tobacco land, and the surface soil and subsoil are lighter gray than in the typical areas.

This soil is the most productive Múcara soil, and many thousands of people obtain most of their living from it. The numerous houses are on the narrow ridges, and the cultivated land is on the slopes. Throughout most areas of this soil are many small tobacco fields, some only a fraction of an acre in extent. Yields depend on the quantity of fertilizer used and the thickness of the surface soil. The average acre yields on this soil are: 800 pounds of tobacco, 1,200 pounds of sweetpotatoes, 400 pounds of beans, 1,200 pounds of yuca, 300 pounds of pigeonpeas, and from 10 to 15 bushels of corn. Other crops yield accordingly.

Múcara silt loam.—Múcara silt loam differs from Múcara silty clay loam in having a lighter textured surface soil and a slightly less heavy subsoil. All areas are well drained, even those at the heads of drainageways. This soil occurs mostly in the eastern part—from Ceiba to Carolina—and a few areas are in the western part.

Areas of this soil that have an unusually large number of stones and boulders on the surface are shown on the map with stone symbols; such areas are used only for pasture and trees. Some of the areas are very steep.

This soil occupies narrow ridges and the upper parts of long slopes. Some areas are used for grassland because their relief is unfavorable for the production of cultivated crops. Some of the more favorably situated areas, which are readily accessible, are used with adjoining soils for the production of sugarcane, but most of the land is used for subsistence crops. Yields are less than on Múcara silty clay loam.

Juncos clay.—Juncos clay is similar to Múcara silty clay loam in color, origin, and consistence, but owing to its smoother relief it has a thicker surface soil, more plastic subsoil, greater depth to parent rock, and is much more productive, especially for sugarcane. Nearly 90 percent of the land is cultivated to sugarcane.

This soil is characterized by a 7-inch dark grayish-brown semi-granular plastic sticky heavy clay surface soil. It is underlain by a 14- to 20-inch layer of yellowish-brown compact plastic sticky clay containing gray specks. Below this layer and continuing for another 10 inches, is a mixture of disintegrated rock and fine-grained yellowish-brown silty clay loam. Below a depth ranging from 30 to 40 inches are tuffaceous rocks.

This soil occupies the lower slopes and low rounded hills throughout the island, in association with the Múcara soils.

Sugarcane produces from 30 to 35 tons of gran cultura and from 20 to 25 tons in ratoon crops. P. O. J. 2878 and S. C. 12/4 are the most common varieties of cane planted on this soil. Subsistence crops and tobacco yield better on this soil than on Múcara silty clay loam.

Sabana silty clay loam.—Sabana silty clay loam differs from Múcara silty clay loam in having a lighter colored surface soil and subsoil, and it is more acid in all layers. In most places it occurs on rolling or steep hills associated with the Múcara soils but occupies areas receiving slightly more annual rainfall. There are many stones and boulders on most of the ridges.

On many of the more gentle slopes this soil has a plastic heavy subsoil, which retards the percolation of water, thereby causing gray spots to appear on the surface. Most of the concave areas or slight depressions have a distinct gray color, indicating that this soil is sensitive to underdrainage and that any abnormalities in the heaviness of the subsoil or additional accumulation of surface water will cause imperfect drainage, which, in turn, causes gray and rust-colored mottlings in the soil layers. On the ridges this soil is friable and well drained, but it is seldom more than 10 inches deep to bedrock. Most of the hills are rounded, and the ravines have sloping sides.

This soil is less desirable than Múcara silty clay loam for all agricultural crops. Probably 80 percent of the land is used for subsistence crops, and the remaining 20 percent is divided equally between pasture and sugarcane.

Sabana silt loam.—Sabana silt loam developed in the eastern part of the island, differs from Sabana silty clay loam in having a lighter textured surface soil and lighter colored more acid subsoil. The land use for these two soils is similar, and both produce about the same yields of crops.

Areas of this soil that have an unusual quantity of stones and boulders on the surface are shown on the map with stone symbols. Such areas are used only for pasture and trees, and many of them are very steep.

Naranjito silty clay loam.—Naranjito silty clay loam is associated so intricately with the Múcara and Sabana soils that in some places it is impossible to separate them. In general, the Naranjito soil occurs in areas receiving more rainfall than areas of either the Múcara or Sabana soils, and it is therefore more acid, has a lighter colored surface soil, and has a tendency to have a reddish-brown or brownish-red shallow subsoil over shale, tuffaceous rock, or in places igneous rock.

The surface soil of a cultivated field of Naranjito silty clay loam has a gray cloddy appearance, with some streaks of red clay that have been exposed, owing to sheet erosion or deep plowing. This layer is plastic, sticky, and strongly acid. It is underlain, at a depth ranging from 2 to 10 inches, depending on the slope and extent of erosion, by a layer that varies within short distances from reddish-brown to yellowish-brown acid plastic sticky clay, which becomes somewhat more friable at a depth of 20 inches and grades into unconsolidated parent rock at a depth of about 30 inches.

This soil is used for the production of minor crops, tobacco, and coffee, but yields are not so good as on the Múcara soils. Farmers not using fertilizer prefer this soil to the Cialitos or Catalina soils for tobacco and minor crops. A large proportion of the land is in pasture. Two acres are required to pasture an animal through the year. This soil occurs on slopes ranging from 40 to 60 percent. In places on the ridges and steeper slopes, there is a rather large number of boulders.

Naranjito silty clay loam, smooth phase.—Areas of Naranjito silty clay loam that have a slope of less than 30 percent are classified as Naranjito silty clay loam, smooth phase. This soil is slightly more desirable than the typical soil, and a larger proportion is in cultivation, especially to subsistence crops. Yields are higher than on the typical soil, and cultivation is usually done with a team of oxen instead of with hand implements, as is the practice on the typical soil.

This soil is associated with the typical soil and, therefore, occurs in areas of rather high yearly rainfall.

Naranjito silty clay loam, colluvial phase.—Areas of Naranjito silty clay loam that occur at the bases of the hills and have a much thicker surface soil and subsoil than typical Naranjito silty clay loam are mapped as a colluvial phase of that soil. Agriculturally the colluvial soil is much more desirable than the typical soil, because it receives the wash from the upper slopes and is therefore more fertile, has a higher water-holding capacity, and is much deeper to parent rock.

This soil is used mainly for subsistence crops, tobacco, and coffee, and areas near roads are used for sugarcane. Yields are about twice as high as those obtained on the typical soil, especially of such crops as sugarcane, coffee, and tobacco.

Río Piedras clay.—Río Piedras clay has a characteristic heavy plastic acid clay surface soil and subsoil, both of which contain various proportions of gray, yellow, and red. The surface soil is plastic and slippery when wet and hard and brittle when dry. There is no sharp line of separation between the soil and the underlying shale parent material, which in most places occurs at a depth of about

2 feet. This soil is acid in all layers. It occurs mostly in the vicinity of Río Piedras, but some areas are near Central Coloso and near Fajardo. Sugarcane, with yields ranging from 25 to 35 tons gran cultura cane, is the best crop grown on this land. Two acres are necessary to pasture an animal in favorable years. Yields of all crops are low, because of the low content of organic matter, strong acidity, and heavy plastic characteristics of all layers. The soil apparently is low in phosphorus. Owing to the plasticity, low fertility, sensitiveness to underdrainage, and susceptibility to erosion, the land requires very careful management.

Río Piedras silty clay loam.—Río Piedras silty clay loam occurs in a few small areas east of Fajardo, and they are very conspicuous, even from a distance, on account of their nearly white surface. A cultivated field has a very light gray or very light brownish-gray silty clay loam surface soil about 10 inches thick, which contains an abundance of small angular shale fragments. The subsoil is grayish-yellow heavy plastic clay mottled with yellow, gray, and red. This material rests on partly weathered shale at a depth of about 3 feet. Along some drainageways the material is composed largely of accumulated shale. This soil is very acid in all layers. The gray color is not caused by imperfect drainage but is due to the light color of the shale from which it is derived and to intense leaching under acid conditions.

This soil occupies sloping and steep hillsides. The less steep areas are used for the production of sugarcane, and the steeper areas are in pasture. Crop yields are lower than on Río Piedras clay. The land requires very careful management, as it is subject to erosion, difficult to cultivate, and low in fertility.

Pandura sandy clay loam.—Pandura sandy clay loam is readily distinguished from most of the other granitic soils, owing to the large number of granite boulders scattered on the surface (fig. 109). This soil occupies extensive areas on steep mountainsides as well as on lower steep hills in the southeastern part of the island near Yabucao and Maunabo.

This soil is characterized by a brown or light-brown granular friable acid gritty sandy clay loam surface soil about 6 inches thick, the thickness depending on the degree of slope and the extent to which erosion has taken place. The steeper the slope the greater the degree of sheet erosion and the thinner the surface soil. The surface soil is underlain by a mixture of loose gritty sandy loam and disintegrated granite of the quartz diorite variety, which gradually changes, at a depth ranging from 12 to 30 inches, to the parent rock.

As this soil is loose, friable, and sandy, it absorbs water rapidly and is excessively drained, but, owing to its occurrence in areas receiving a rather high monthly precipitation, crops produced on it do not suffer greatly from drought.

Owing to the steepness of the relief and the exceptionally high content of boulders, this soil is used principally for pasture and trees. The smoother rock-free areas are used advantageously for the production of minor crops and tobacco, which, when the land is sufficiently fertilized, produce crops comparable to those obtained on Múcara silty clay loam. Crops growing continuously on this soil for a number of years show evidence of lack of nitrogen. A characteristic feature of areas of this soil is the large boulders which are nearly concealed

FIGURE 109.—Large boulders on Pandura sandy clay loam near Las Piedras. Mango trees on the right side of the hill.
Peñones en un Pandura areno-arcilloso lómico cerca de Las Piedras. Arboles de mangó a la derecha de la colina.

by banana and plantain plants. Some of the coffee trees are nearly hidden by the banana plants. Many of the areas in which boulders are numerous are shown on the map with stone symbols.

Pandura sandy clay loam, smooth phase.—Areas of Pandura sandy clay loam that have smooth relief, such as slopes ranging from 15 to 30 percent, are classified as Pandura sandy clay loam, smooth phase. The total area of this soil is only a small fraction of that of the typical soil.

Owing to the relief, this soil is more easily cultivated and has thicker layers than the typical soil. For these reasons, it is more desirable and generally sells at a higher price. A higher proportion of the land is in minor crops than in pasture or trees. Yields are about the same as on areas of Cayaguá sandy clay loam, steep phase, a soil the Pandura soil closely resembles.

Pandura loam.—Pandura loam differs from Pandura sandy clay loam in that it has a more loamy texture in all layers. It is less productive than Pandura sandy clay loam. In many places the two soils are closely associated, and the crop use is nearly the same for both soil types. The loam requires slightly more fertilizer than the sandy clay loam.

Pandura loam, smooth phase.—Areas of Pandura loam that have rather smooth relief are classified as Pandura loam, smooth phase. The total area of this soil is almost 22,000 acres.

This soil has a fairly thick surface soil and a thin subsoil above the same kind of parent material that underlies the typical soil. Owing to the relief and slightly thicker surface layer, this smoother soil is used mostly for the production of subsistence crops and to only a small extent for trees and grass. Yields are higher than on the typical soil. Cultivation is mostly by hand, as this soil, although smoother than the typical soil, is classified as rather steep.

Cayaguá sandy clay loam.—Cayaguá sandy clay loam is closely associated with the Pandura soils, from which it is readily distinguished by the presence of a small quantity of rocks or boulders on the surface and the less steep relief. In reality Cayaguá sandy clay loam is a complex of several different soils so intimately associated that they could not be separated on the map.

The 6- or 8-inch surface soil of Cayaguá sandy clay loam is light grayish-brown loose friable acid sandy clay loam that readily forms a good tilth when cultivated. Underlying the surface soil and continuing to a depth ranging from 14 to 20 inches is yellowish-brown, in places reddish-brown, rather heavy slightly stiff sandy clay, which gradually changes to loose coarse gritty quartz diorite material at a depth of about 30 inches. The compaction and depth of the subsoil varies greatly from place to place and within short distances. In concave areas or on very gentle slopes, the layers are thick, drainage is slightly impeded, and the subsoil is reddish brown and much more compact than on the convex slopes or the steeper areas. In the latter areas the layers are thin and the soil is friable and excessively drained.

This is one of the best soils for the production of tobacco in the San Lorenzo tobacco district (fig. 110), as it is well drained, warm, and friable. It requires larger quantities of fertilizer than Múcara silty clay loam in order to produce the same yield of tobacco.

The largest acreage of this soil is used for tobacco, followed by pasture, corn, beans, upland rice, sugarcane, and sweetpotatoes, ranking in acreage in the order named.

The principal variety of tobacco grown is Virginia Blanca, which yields from 500 to 1,200 pounds to the acre, depending on the quantity of fertilizer used, management of the land, and whether the crop is grown on concave or convex slopes. The best pastures have a carrying capacity of about 1½ acres to an animal, but the feed produced from this acid-leached nonfertilized soil is not so nutritious as that furnished from the grass growing on the Colinas or Descalabrado and related soils. Corn produces from 1,300 to 1,600 pounds an acre in fields from which tobacco has been harvested. The corn roots obtain the benefit of some of the fertilizer applied for the tobacco. Beans yield

FIGURE 110.—Cayaguá sandy clay loam south of San Lorenzo. Tobacco has been picked, and the land is now in corn and beans; a few months later it will be planted again to tobacco.

Cayaguá areno-arcilloso lómico al sur de San Lorenzo. El tabaco ya ha sido recolectado y la tierra está ahora sembrada de maíz y habichuelas; pocos meses después la tierra será sembrada otra vez de tabaco.

from 200 to 300 pounds to the acre. The common practice is to plant corn and beans together immediately after the tobacco is harvested. Upland rice yields form 600 to 900 pounds to the acre. Usually it is planted in March or April following tobacco and is harvested 5 or 6 months later. Sugarcane yields about 25 or 30 tons to the acre, sweetpotatoes from 4,000 to 5,000 pounds, yautias from 5,000 to 8,000 pounds, and yuca only about 1,000 pounds.

Throughout areas of this soil there is much evidence of lack of nitrogen, as the tobacco, corn, and even bananas have a pale-yellow color. The land is subject to erosion unless very carefully handled. The methods used to prevent erosion are brush terraces and gridiron-shaped ditches spaced about 20 feet apart.

Cayaguá sandy clay loam, steep phase.—The steep areas of Cayaguá sandy clay loam, occurring on both sides of the drainageways, are classified as Cayaguá sandy clay loam, steep phase. This soil occupies 17,408 acres and is used only for pasture. It includes not only the

steep slopes of the ravines but also narrow strips of level deep sandy material in the bottoms of the U-shaped drains, which are overflowed during rains but are dry and grass-covered during dry periods. A swamplike vegetation grows in some of the wet areas, but such areas are very small. The soil on the catstep slopes is friable, and the parent rock lies nearer to the surface than in the typical soil.

Areas of this soil are considered good pasture land, but it takes about 2 acres to pasture an animal a year.

Ciales clay loam.—Ciales clay loam is derived from granite. It occurs in large areas in many parts of the island. Some of the largest are near Ciales, Morovis, and Utuado. This soil occupies hills having slopes ranging from 40 to 100 percent, and it is characterized by a grayish-brown gritty granular clay loam surface soil about 4 or 6 inches thick, underlain by mottled red and yellowish-brown gritty sandy clay. In many places the subsoil would analyze gravelly sandy clay. The subsoil material breaks into small gravel, coarse sand, and single grains of sand and silt, and this is the most compact layer in the profile. It rests on decayed granite at a depth ranging from 8 to 20 inches. This soil is strongly leached and is very acid in reaction.

In most places, especially on the ridges, the soil is shallow and somewhat droughty. It requires barnyard manure or fertilizer to maintain its fertility, and erosion in most areas is serious unless the land is very carefully managed. Some areas of this soil near Utuado are used for the production of sugarcane, and the yields average between 25 and 30 tons an acre. The areas near Ciales are used mainly for pasture and subsistence crops, and the areas near Morovis mostly for subsistence crops and tobacco and to less extent for pasture.

Ciales clay loam, smooth phase.—Areas of Ciales clay loam occupying colluvial slopes and having rolling relief are classified as Ciales clay loam, smooth phase. This soil is very much less extensive than the typical soil, but it is more desirable and a higher proportion of it is planted to cultivated crops. Fertilizers are required for good yields and, even with the use of such amendments, the crops are often of a light-green color, showing a deficiency of nitrogen in the soil.

This soil grades so gradually into the typical soil that it is nearly impossible to separate the two, and, in many places, some areas of the smoother soil are included with the typical soil.

Ciales loam.—For the most part Ciales loam occurs in the vicinity of Patillas. This soil differs from Ciales clay loam in that it has a looser, more friable, and sandier surface soil. In other respects the two soils are the same, and the fertility of the two is about equal. The loam occurs in areas having less rainfall than areas of the clay loam, and therefore leaching has not been so great. Both soils, however, need fertilizer or manure in order to produce profitable yields.

Much of the land near Patillas is planted to sugarcane, but yields are low, especially during dry years. Yields of 15 or 20 tons of sugarcane are common during an average year when an application ranging from 600 to 700 pounds of fertilizer is used. Other areas of this soil are used for minor crops, pasture, and coffee.

Ciales loam, smooth phase.—The smooth phase of Ciales loam occurs on colluvial slopes and low rolling hills. It is associated with the typical soil and is considered more desirable for all cultivated crops. This soil has thicker layers and a slightly higher organic content than

the typical soil. Sugarcane growing on this soil seldom yields more than 30 tons an acre.

Ciales loam, colluvial phase.—Ciales loam, colluvial phase, occurs for the most part southeast of Patillas in the eastern part of the island. It is associated with Ciales loam and is used for the same crops, although it is more productive, and higher yields of all crops are obtained.

Ciales loam, colluvial phase, consists of material that is in part residual from granite rock and in part accumulated from surface wash and creep from upper slopes. This soil, owing to its depth and the continual wash from the upper slopes, is more fertile and more productive than Ciales loam. It is considered more desirable and sells for a higher price than typical areas of Ciales loam or Ciales loam, smooth phase.

This soil is used for the cultivation of tobacco, subsistence crops, and coffee, all of which yield fairly well when fertilizer or manure is added to the land.

Teja loam.—Teja loam is one of the poorest soils derived from granite in Puerto Rico, because both the soil and the soil-forming material are coarse and low in plant nutrients. During dry periods this soil is droughty, and during wet periods water percolates through the loose friable surface soil so fast that it carries plant nutrients with it. The subsoil is compact enough to prevent water from penetrating it as rapidly as it does the surface soil; therefore surplus water accumulates on the subsoil and eventually starts flowing laterally to some outlet or drainageway. Thus the lower part of the subsoil is deprived of needed moisture, and some plant nutrients are carried away by the drainage waters.

In a cultivated field this soil is characterized by a light-gray gritty granular light loam or sandy loam surface soil, from 4 to 8 inches thick, which is underlain by gray gritty compact sandy clay loam that is reddish brown in places. This layer is about a foot thick and rests on firm gritty coarse-grained more or less weathered quartz-diorite granite.

Areas of this soil have favorable relief for cultivation, but, owing to the characteristics of the soil material, caution must be used in farming the land, otherwise sheet erosion would be destructive. The largest acreage of this soil is used to supply the needs of several hundred people for subsistence crops, such as sweetpotatoes, beans, corn, and yautias. A few acres are used for the production of tobacco and sugarcane, but yields of all crops are low, even with the use of fertilizer. As the inherent natural productivity of the soil is low, much nitrogen must be added. Manure has more lasting effect than commercial fertilizers on this and related soils. Teja loam is valued at less than $20 an acre.

Teja loam, steep phase.—Areas of Teja loam that have hilly or steep relief are mapped as a steep phase. This soil is even poorer than the typical soil because of its steep relief, which is more favorable for the activities of sheet erosion in causing damage to the steep hills that are cultivated to minor crops.

This soil has a 2- to 4-inch gray gritty loam surface soil that rests on a thin compact sandy clay subsoil or directly on coarse gritty granitic material. On many of the ridges, the parent rock is exposed, and vegetation is greatly reduced. In grass-covered areas, the surface

soil is not only two or three times as thick is in cultivated areas but it is very much darker.

Most areas of this soil are used for pasture, which is inferior to that on the Daguao or Múcara soils.

Teja loam, eroded phase.—The eroded phase of Teja loam has a much heavier more plastic subsoil than the typical soil, because the original loamy surface soil has been removed by sheet erosion and the subsoil is exposed. The eroded soil is associated with the typical soil near the mouth of Río Candelero. The land is used principally for pasture and to less extent for minor crops. The relief ranges from rolling to hilly.

Utuado loam.—Utuado loam covers many square miles of rolling and very steep hills in the vicinity of Utuado. This soil is derived from rather fine-grained granite and occurs where the rainfall is sufficient to leach readily the bases and plant nutrients from the soil. Few granite boulders occur on the hilltops or slopes. This feature is in contrast to most of the granite areas.

This soil has a gray or light grayish-brown, friable, semigranular acid loam or sandy loam surface about 7 inches thick, underlain by slightly heavier slightly more compact similar colored loam or sandy clay loam, about 12 inches thick. This layer, in turn, gradually changes to the partly disintegrated granite rock.

This soil is excessively drained both externally and internally. Drainageways are numerous, and the area occupied by this soil is the most eroded section of the island. The slopes are steeper and the ridges more knife-edged than elsewhere. This soil is rather productive, however, and many thousands of people obtain a living from it by growing small patches of tobacco, beans, corn, and sweetpotatoes on their best land and pasturing a goat or two and possibly a cow on the poorest or steepest parts of their small tract. Some concave slopes are used for the production of coffee, which grows very well when the land is fertilized. The soil is low in plant nutrients, and heavy applications of manure or complete fertilizers should be used in order to maintain its fertility.

Virgin areas have a higher organic-matter content and a much darker and deeper surface soil than cultivated areas. All layers of this soil are acid, and the land would be benefited by the application of about 1½ tons of lime every 3 or 4 years.

Sheet erosion is partly controlled on this soil by crudely constructed brush and stick terraces built with the contours, also by the planting of hedgelike strips of guinea grass on the steep hillsides. The hedge is more effective after it becomes established, and it can be cut during certain seasons and used for cattle feed without losing its effectiveness.

Acre yields on this soil are as follows: Sweetpotatoes about 2,000 pounds, yautias about 1,500 pounds, beans about 400 pounds, corn from 300 to 500 pounds, and yuca from 400 to 600 pounds. Ordinarily yields are increased when the land is protected by properly constructed brush terraces.

Utuado loam, smooth phase.—Utuado loam, smooth phase, has physical and chemical characteristics similar to those of the typical soil, but the land is not so steep; therefore, it is considered a better agricultural soil and is more productive. Sheet erosion is less on this soil than on the typical soil, and a higher proportion of the land is in

cultivated crops. As it occurs in such intimate association with Utuado loam, the boundaries between the two soils are drawn arbitrarily in many places.

Vieques loam.—Vieques loam occurs only on the Isla de Vieques. It is derived from material similar to that underlying Pandura loam, but as it occurs in sections having much less annual rainfall, it is less acid and darker than the Pandura soil.

In a virgin area Vieques loam has a very dark grayish-brown or nearly black single-grained friable loam or sandy clay loam surface soil about 8 inches thick that contains an abundance of grass roots, is neutral or alkaline, and is rather high in organic matter. Many granite boulders are scattered over its surface. The subsoil, to a depth of 18 inches, is reddish-brown gritty sandy clay loam that is slightly plastic when wet. Underlying this layer, between depths of 18 and 30 inches, is partly disintegrated coarse-grained granitic material, which is slightly alkaline in reaction. This soil is well drained and easily cultivated, but at present, owing to the lack of rainfall, more than 60 percent of its area is in pasture, mostly of guinea grass, which is more nutritious than the grass grown on the Pandura soils. Sugarcane, tobacco, and cotton grow fairly well. The yield of sugarcane is low, except in exceedingly wet years.

Vieques loam, undulating phase.—Areas of Vieques loam that occupy positions having undulating relief are mapped as an undulating phase of that soil. This undulating soil is more desirable than the typical soil because of its more favorable relief and because more moisture is retained than in the typical soil.

Nearly all of this soil has been or is now planted to sugarcane. On account of the climate, the average yield is low compared to yields from similar soils in the mainland of Puerto Rico. Fertilizer, when applied to the nonirrigated soils in the dry sections, reduces rather than increases crop yields, because when the fertilizer is applied the plant roots do not need to penetrate to so great a depth in search of plant nutrients and, during the dry season, instead of being deep rooted and having a large area from which to obtain moisture, they are shallow rooted and die from lack of moisture. Planting the sugarcane in the bottoms of rather deep furrows is the common practice in such dry areas. A yield of 15 tons of sugarcane to the acre is considered a good yield on this soil for an average year. Guinea grass grows equally as well on this soil as on Vieques loam.

Vieques loam, colluvial phase.—The colluvial phase of Vieques loam is the most productive and most desirable soil of the Vieques series. It occupies an intermediate position between Vieques loam, undulating phase, and soils of the terraces and bottoms. Most of it is cultivated to sugarcane, which yields from 15 to 20 tons an acre. The remainder is in guinea grass which is productive and nutritious.

This soil is similar to Vieques loam, except that the surface soil is darker, more fertile, and slightly more acid. The depth to granite rock also is much greater, and, therefore, the water-holding capacity is greater than in the more shallow areas of the typical soil.

Vieques loam, colluvial phase, occurs only on the islands of Vieques and Culebra.

SHALLOW SOILS OF THE UPLANDS

The shallow soils of the uplands include 37 soil types and phases of 19 soil series, in addition to rough stony land. Their total acreage is greater than that of any other group of soils. The soils in this group occur throughout the entire upland part of Puerto Rico, and, as the group name implies, all are very shallow. Many are stony. The parent rock lies at a depth of less than 18 inches from the surface. These soils have a wider variation in relief and rainfall than the soils of any other group. The climate ranges from arid to humid, and the relief ranges from level to precipitous. Owing to the rockiness, shallowness, unfavorable relief, dry climate, or a combination of one or more of these features, grass covers from 60 to 65 percent of the area, trees occupy about 15 percent, brush about 15 percent, and subsistence crops and coffee only 5 to 10 percent.

In less densely populated countries most of the soils in this group probably would be classified as rough stony land and would be dis-

FIGURE 111.—Subsistence crops on Múcara silty clay loam, steep phase. In some places this kind of land would be classified as rough stony land and be described as nearly nonagricultural but the pressure of population is so great in Puerto Rico that many thousands of people farm these 60- and 80-percent slopes. Note the houses on the Λ-shaped ridge top.

Frutos menores en Múcara limo-arcilloso lómico, fase escarpada. En algunos sitios esta tierra sería clasificada como tierra quebrada pedregosa y descrita como casi inservible para la agricultura, pero la presión de la población es tán grande que millares de personas trabajan estas laderas de 60 y 80 por ciento de declive. Nótese las casas en la cresta del monte en forma de Λ.

cussed as having little or no agricultural importance. The pressure of population is so great, however, that many thousands of people are forced to live on these rough, rocky, steep (fig. 111) hills which have shallow soils, and they obtain a large part of their living by raising a few chickens, goats, pigs, or cattle. In favorable years they produce some subsistence crops from small patches of their best land. Owing to the large number of inhabitants and the high value of this land, more

careful separation was made of these shallow soils than ordinarily would be made.

This group includes soil types of the Colinas, Soller, Aguilita, Tanamá, and Ensenada series, all derived from Tertiary limestone; of the San Germán and Lajas series, derived from Cretaceous limestone; of the Jácana, Descalabrado, Guayama, Daguao, Múcara, Picacho, and Naranjito series, derived mainly from Cretaceous shales and tuffs, and in part from igneous rocks, mostly andesitic; of the Mariana and Yunes series, derived from shale and rhyolite; of the Juana Díaz series, derived from sandstone; of the Vieques series, derived from granite; of the Rosario series, derived from serpentine; and rough stony land, derived mostly from hard igneous rocks.

Owing to the soil characteristics and climatic environment, the two outstanding uses for these soils are forestry in the humid sections and the production of grass in the arid, semiarid, and subhumid sections. The raising of cattle for milk, beef, and draft purposes is by far the most important livestock enterprise, and the value of the cattle is much greater than that of the timber produced.

Most of the soils used extensively for pasture produce an excellent quality of grass, because these soils are young, owing to their steep relief or shallowness, and they have not been leached of their bases and plant nutrients to nearly so great an extent as the older, deep soils occurring in the areas of high rainfall. In addition, the soil material within easy reach of plant roots is constantly being rejuvenated by the weathering of the shallow-lying easily disintegrated parent rock. This favorable soil characteristic, combined with a nearly continuous growing period, makes the pastures superior to those of much of the grassland in the United States. On these soils of the uplands, the best pasture is produced on the long gentle slopes where the rainfall is adequate for continuous plant growth but not sufficient to cause serious leaching of plant nutrients from the soil.

Very few, if any, farmers fertilize their pastures. Weeds or brush are obnoxious in certain areas and must be cut once every 2 or 3 years. Some abandoned pastures have been nearly covered with brush and weeds within 5 years' time. The most serious pests in the pastures are guava trees, which spread rapidly in the humid and subhumid areas; zarzarilla (fig. 89), a bush that infests the pastures of the arid sections; and guayacán blanco, or guayacanillo, a noxious weed growing on shallow soils derived from limestone. This weed, especially during pollination, causes irritation of the eyes of the livestock. If the zarzarilla is eaten by the animals it apparently causes them to lose some of their hair.

The most common permanent grasses in the humid areas are grama and cerrillo, with yaragua, or molasses grass, elephant grass, and Guatemala grass the principal planted grasses. In the semiarid areas, guinea grass is the principal cultivated grass and Mexican bluegrass, or horquetilla morada, is the most important native grass. In the arid section, Bermuda grass is the predominant grass, with some guinea grass.

All the soils in this group are adequately or excessively drained, with the exception of a few local seepy areas, and most of the areas are dissected by hundreds of drainageways. Most of the streams flowing

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through the arid and semiarid districts, however, are dry most of the year. Water for both beast and man is more difficult to obtain than in almost any other part of the island. Dug wells, operated by windmills, along the shore and in the valleys supply most of the water for the livestock grazing on the hills. The water near the shore is so brackish that additional salt for the livestock is not necessary. The average depth of the wells is about 35 feet.

In Vieques and Culebra the water supply, rather than the quantity of grass, determines the carrying capacity of the land.

The areas of these soils used for forestry are well adapted for the growing of trees. The climate in certain areas favors some species and eliminates others, but the range in climatic conditions on these different soils is sufficient for the growth of any tree grown in Puerto Rico. Forestry is not so important as it has been or as it might be.

Virgin forests are of limited extent, and the only fairly large areas are within the Caribbean National Forest; other areas have been cut over repeatedly. Practically no systematic plantings have been made on private lands. The trees grow and reproduce by natural selection and natural elimination. When a tree is marketable it is cut and sold. Within the last few years the Insular Forest Service and Federal Forest Service have greatly enlarged their holdings and improved their land by building roads and planting many additional species of trees. Many valuable trees, such as mahogany, cedro, tabonuco, guayacán, or lignumvitae, sabino, granadillo, and maricao, grow on some of the soils of this group.

A common practice among the jibaro farmers is to cut the timber and make it into charcoal. This enterprise gives a cash income, but it cannot be recommended, as it seriously reduces the natural resources of the island.

To facilitate the discussion of these soils, those derived from the same or similar materials will be described briefly, and each soil type will be discussed in detail.

Colinas clay loam, steep phase; Colinas stony clay loam; Colinas stony clay loam, steep phase; Soller clay loam; Soller clay loam, shallow phase; Soller clay loam, hilly phase; Soller clay loam, steep phase; Aguilita clay; Aguilita stony clay; and Aguilita stony clay, shallow phase, are all dark-colored plastic granular soils derived from soft or medium-hard Tertiary limestone. Owing to low rainfall, thin soils, or both, these soils are predominantly used for pasture. They all have some rocks or rock fragments on the surface, the quantity of which varies greatly from place to place. The Soller soils occupy areas receiving from 80 to 100 inches of annual rainfall; the Colinas soils receive slightly less, or from 55 to 80 inches; and the Aguilita soils receive the least, from 35 to 55 inches. The amount of rainfall is reflected in the color of the soils, vegetation, and crop use. The Soller soils are nearly black, the Colinas soils are dark grayish brown, and the Aguilita soils range from brown to dark grayish brown. The vegetation on the Soller soils is mostly mesophytic, and on the Aguilita it is mostly xerophytic. The Colinas soils have some of each. Owing to the high rainfall, the Soller soils have more areas in cultivated crops than have the soils of either of the other series. They are also better for grass.

All these soils are susceptible to erosion under improper management because of their plastic sticky consistence, high lime content, and soft granular structure, which cause the soil to wash away under the dashing tropical showers. The Soller soils have been eroded to a greater extent than the other two soils on equal slopes. The predominant subsistence crops grown are pigeonpeas, corn, beans, and sweetpotatoes, and cultivation of all these crops, except sweetpotatoes, induces erosion.

Owing to the steepness of the relief and porous nature of the lower substratum, these soils are excessively drained. Few drainageways cross areas of these soils, however, and the water penetrates to underground channels. Water for both man and beast is difficult to obtain in many places, especially during dry periods. Within the rough limestone hills receiving more than 80 inches of rainfall, springs are fairly numerous, but in the drier areas, water must be caught from the galvanized roofs of houses or carried a long distance. No wells are drilled in these soils derived from limestone. A few of the hundreds of sinkholes throughout areas of these soils hold water for several months.

Tanamá stony clay, Ensenada clay, and Ensenada clay, shallow phase, are red or reddish-brown permeable slightly plastic softly granular neutral to alkaline soils derived from hard Tertiary limestone. The Ensenada soils occur in areas having less than 35 inches of rainfall, and therefore the predominant type of vegetation is desert shrubs. The Tanamá soils receive from 70 to 90 inches of annual rainfall. They produce a mesophytic vegetation consisting of moca, moral, roble, guaba, capa prieta, ausubo, maría, and guaraguao trees, besides many kinds of small plants.

Sisal has been planted in a few places, but the projects have been abandoned. The centuryplant, or maguey, grows very well on this soil, indicating that the related sisal could be grown on large tracts of this and similar soils in the arid and semiarid sections.

San Germán clay, Lajas clay, and Lajas clay, rolling phase, are derived from Cretaceous limestone. They occur on rolling or precipitous relief, north of the Aguilita soils. These soils are shallow and stony and are used for pasture and forestry. The San Germán soils occur in drier areas than the Lajas soils and for that reason are generally less valuable. Many areas of the Lajas soils, however, are simply limestone outcrops and have no agricultural value.

All the soils of the Jácana, Descalabrado, Guayama, and Picacho series, as well as some soils of the Daguao, Múcara, and Naranjito series that have been classified with this group, are derived from Upper Cretaceous shales, stratified ash and tuff, massive andesitic tuff, and conglomerates. These different rocks are intimately associated, and although each has some influence on the soil directly above it, the mappable soil characteristics are influenced to a greater extent by soil climate than by geology. These soils have many characteristics in common. They are brown or tinged with brown, are shallow, and occur for the most part on high, narrow Λ-shaped ridges and upper parts of slopes. Natural drainage is adequate or excessive. Owing to the rockiness, shallowness, unfavorable relief, dry climate, or a combination of one or more of these factors, grass covers from 75 to 85 percent of the land, and brush, trees, coffee, tobacco, and minor crops occupy the remainder.

The elevation of these soils ranges from sea level along the arid south coast to the high rainfall areas of the interior. Listed in the order of increasing quantities of rainfall received they are: Jácana, Descalabrado, Guayama, Daguao, Múcara, Picacho, and Naranjito soils. Some of them occur in areas having high precipitation, but, owing to their very steep relief, they receive less soil moisture than soils with much less steep relief in areas having less annual rainfall.

A close correlation exists between the soil moisture received and the color and pH value of the soils. Generally speaking, the greater the rainfall, the lower the pH value. Thus, the Jácana soils have the highest pH value, about 7.5, and the Naranjito soils the lowest, less than pH 5.0. The color of the Naranjito soil in the highest rainfall area is slightly red. With decreasing rainfall, the soils become darker. The Daguao soils receive about 65 inches of mean annual rainfall and are nearly black, but as the rainfall decreases the soils become brown, passing by degrees from very dark grayish brown to chestnut brown. The Jácana soils in the driest areas are light brown.

The Jácana, Descalabrado, and Guayama soils occur in the dry section, and nearly all of their area is used for pasture. This area resembles the cattle country of the western Great Plains of the United States, as many large cattle ranches are located on these soils. The common practice is to plant guinea grass after clearing the land of brush and cacti. The grass is of excellent quality, and in general the cattle pastured on these alkaline soils are in good health, sleek, and have firm hard flesh during the rainy season. The grass stops growing soon after the dry season begins, but it cures well and has much strength. It resumes growth and grows very rapidly when the rainy season starts. Based on the natural productivity of the soils, the quantity of grass produced decreases with an increase in slope of the land, with shallowness of the soils, and with a drier climate. Therefore, within each soil type, the carrying capacity has a wide range, as each soil occurs over a rather wide range in climate. In average areas, Jácana clay is the best soil, followed by Descalabrado silty clay; Descalabrado silty clay, rolling phase; Descalabrado silty clay, eroded phase; Guayama clay, colluvial phase; Guayama clay, Descalabrado silty clay, shallow phase; and the very stony areas of Guayama clay.

Most of the streams within this area are dry during the winter, and windmills located in the valleys supply water for the cattle, as well as for the ranchers. With the exception of areas of Descalabrado silty clay, eroded phase, and Descalabrado silty clay, shallow phase, this is probably the most sparsely populated part of Puerto Rico, excluding the national forests.

The Daguao, Múcara, Picacho, and Naranjito soils receive sufficient rainfall for the production of trees and minor crops, and the proportion of their area in grass is not so high as that of the Jácana, Descalabrado, and Guayama soils. Based on their natural productivity, the Daguao soils are the strongest, followed by the Múcara, Naranjito, and Picacho soils. The Múcara and Naranjito soils included in this group are: Múcara silty clay loam, steep phase, Múcara silty clay loam, shallow phase, Múcara silt loam, steep phase, and Naranjito silty clay loam, steep phase.

The Yunes and Mariana soils are not derived from similar material, but they have many characteristics in common. The Yunes soils are derived from acid bedded shale and the Mariana soils from rhyolite, fused glassy rock, and possibly some sandstone. The soils of both series are nearly white, strongly acid, plastic, single grained, and very shallow. The Yunes soils are used mostly for forestry and pasture. The Mariana soils are used for pasture and forestry in the eastern part and for pineapples and pasture in the area near Lajas.

The Juana Díaz soils are the only soils derived from sandstone. They occupy less than 1,000 acres and occur near Juana Díaz. In many characteristics they resemble the Plata soils.

The Rosario and Nipe soils are the only two soils derived from serpentine rock, and in most places they are closely associated. The Nipe soils are deep and occupy the mesas, or tablelands, and gentle slopes; the Rosario soils are shallow and occupy the steep slopes. The deepest areas of them are along the concave slopes where soil washes from adjacent slopes and, as the concave slopes have more soil moisture, the soil-developing processes are more active than in adjacent areas; therefore, the serpentine rock is weathered to a greater depth.

Colinas clay loam, steep phase.—The steep phase of Colinas clay loam differs from the typical soil, previously described, in that it occurs on steeper relief and is used almost entirely for pasture. A few small patches are used for pigeonpeas, beans, and corn near the peons' homes.

The surface soil is grayish-brown or dark grayish-brown granular nearly neutral clay loam, from 2 to 4 inches thick, which becomes black and very plastic when wet. This layer rests on light yellowish-brown clay loam that is slightly heavier, more alkaline, and more plastic than the surface soil. At a depth ranging from 8 to 12 inches, depending on the relief, the gray medium-friable calcareous parent limestone is reached. In a few eroded spots the limestone is exposed, thus decreasing the productivity and the value of the land.

This soil occurs on the steep slopes and ridges of the soft limestone section, from Carolina to Aguada. The largest bodies are between Quebradillas and Manatí.

This soil is valued at prices ranging from $20 to $40 an acre, depending on its location. It is considered one of the best soils of the uplands for the production of good-quality grass, and in most places 2 acres will maintain a cow during the year, without causing overgrazing or serious erosion. The grass most commonly produced is a broad-leaved spreading grama, which is both highly nutritious when grown on these alkaline soils and is also a good plant to prevent soil erosion, as it covers the ground, thereby preventing the water from floating the soil granules down the slope.

This soil varies considerably from place to place, especially in the thickness of the surface soil. Near the bases of the slopes, it may be from 8 to 12 inches thick, but near the hilltops the subsoil may be only 1 or 2 inches below the grass mat.

The mean annual rainfall on this soil is high, but, as the soil is derived from soft limestone and is young, it has not been leached of its plant nutrients to nearly so great an extent as old soils derived from shale or granite and receiving the same amount of rainfall. In most places the organic matter is high, and, owing to the porosity of the

limestone, grass roots penetrate deeply for water and available plant nutrients.

Colinas stony clay loam.—Colinas stony clay loam (fig. 112) is one of the poorest soils derived from limestone. In most places it is less than 3 inches thick and consists of a mixture of numerous small limestone rock fragments and granular calcareous grayish-brown clay loam that rests on fairly hard limestone. Fossils resembling giant oystershells are common on the surface. In many places the flat hilltops are bare of both soil and vegetation. This soil occupies low flat hills extending from Río Manatí to Aguadilla.

Agriculturally, this soil is submarginal and is used only for pasture, with the exception of a few acres that are planted to onions and sweetpotatoes, which grow in nearly pure soft limestone rock. The grass is of good quality, but the quantity produced to the acre is low, especially in the driest areas or where small trees, weeds, and brush reduce

FIGURE 112.—Typical view of Colinas stony clay loam. Note the numerous areas of exposed rock. This area is almost continuously fanned by the northeast trade winds, and their effect on the trees and bushes readily can be seen.

Vista de un Colinas pedrego-arcilloso lómico. Véase las rocas expuestas. Esta zona es soplada contínuamente por los vientos del noreste; puede verse su efecto en los árboles y malezas.

the carrying capacity of the land. It is reported that one variety of weed, guayacán blanco, growing on this soil is injurious to the eyes of livestock.

This land is valued at less than $5 an acre, and it is difficult to find a buyer for it even at that price.

The general appearance of the farms on this soil shows little evidence of prosperity. Most of the houses are small—one-room thatched buildings with a lean-to for cooking. The average number of livestock owned by the jibaro farmer includes a few chickens and one or two goats or pigs. The larger landowners have, in addition, a few oxen and one or two horses.

Colinas stony clay loam, steep phase.—The steep phase of Colinas stony clay loam differs from the typical soil in that it has steeper slopes and is slightly more stony. In most areas it would be classified as rough

stony land, as limestone rock is exposed over most of its surface. It occurs along drainageways and along the escarpment near the north coast from Río Manatí to Punta Borinquen. Neither grass nor crops grow on this soil, and the production of trees, for use in making charcoal, is the dominant enterprise. The land is considered non-agricultural but not worthless, as both trees and brush grow surprisingly fast, considering the lack of soil. Large trees will grow in the crevices or on the medium-hard limestone rock, which does not have any visible evidence of organic matter or true soil material. The tree roots do not seem to have any difficulty in penetrating the limestone for moisture and plant nutrients.

Soller clay loam.—Most of Soller clay loam is not so productive as Soller clay, previously described, because it is less deep, owing to erosion, which has been accelerated (1) because of the rolling relief, and (2) because most of this soil is owned by small landowners who continuously plant subsistence crops requiring clean cultivation.

This soil in a virgin field now in grass has a nearly black granular heavy clay loam surface soil about 6 inches thick, underlain by dark-gray friable clay loam mixed with much soft limestone. Below this layer, at a depth ranging from 10 to 14 inches, is slightly hard limestone. On account of the high rainfall, if this land has been in pasture for a number of years, an acre or less will supply food for one animal throughout the year. Under average practices of cultivation, when this soil is planted to subsistence crops much of the rich black soil is lost by erosion, and the fields become less and less productive as erosion continues. Soon only bare limestone is left where there once was rich black productive soil. Rock outcrops are numerous on this soil. There is a house on nearly every 10 acres, and small patches of beans, pigeonpeas, sweetpotatoes, yautias, and corn surround practically every home. Crop yields depend on the length of time the fields have been under cultivation; they are about one-half as large as they were 20 years ago. Practically no fertilizer is used, and each year acre yields become less and less, except in the few small pockets or waterless ravines, which catch the wash from the hillsides. The latter areas, if large enough to be shown on the map, are classified as Camagüey clay.

Most of Soller clay loam occurs between San Sebastián and Central Soller.

Soller clay loam, shallow phase.—The shallow phase of Soller clay loam is associated mainly with the typical soil in the vicinity of Central Soller. It has the same general characteristics as Soller clay loam, but the surface soil and subsoil (if present) are much thinner. This soil, although nearly level and well drained, is less valuable than the typical soil, because it is more shallow and, therefore, is less productive for all crops. It occurs in rather large areas. Owing to the relief, there would be little or no erosion and the depth of the profile should be greater rather than less than in typical Soller clay loam, were it not for the fact that the parent limestone of this shallow soil apparently is of slightly different composition from that underlying the typical soil and weathers much more slowly.

Fewer houses are built on this soil than on the typical soil, but the houses are still very numerous, considering the poorness of the land. Most of the land is used for pastures and subsistence crops. Yields of the cultivated crops are very low, and it requires about 3 acres of

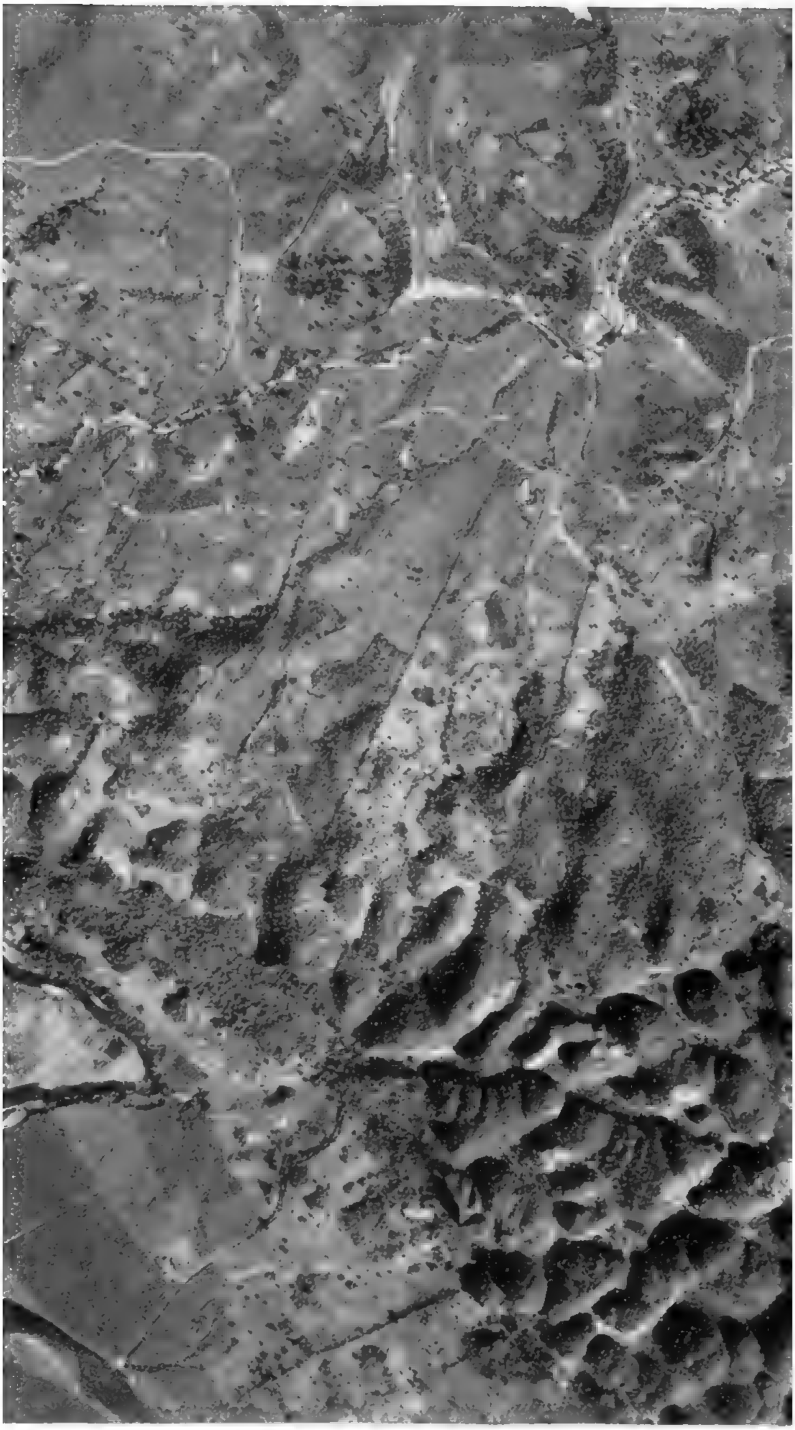

FIGURE 113.—See legend on page 233.

pasture land to feed an ox for a year. There are a few springs on this soil, even on flat hilltops. This adds greatly to the value of the land, as the water supply is limited in this section.

Soller clay loam, hilly phase.—In general, the hilly phase of Soller clay loam is rougher and steeper than Soller clay loam, shallow phase, and fewer people make a living on it. It has a 6-inch granular friable black calcareous clay loam surface soil, which is plastic when wet, overlying medium-hard white limestone. Most areas of this soil are south of the areas of the shallow phase of Soller clay loam. The soil produces fair to good grama grass and is best adapted for pasture. Generally 1¼ acres of pasture land will maintain an animal for a year. On the concave slopes, where there is a rather deep accumulation of soil, corn and tobacco grow well. Sweetpotatoes and beans are grown on the shallower areas and near the small huts. All cultivation is done by hand. Rock piles are conspicuous in the cultivated fields.

Soller clay loam, steep phase.—Areas mapped as Soller clay loam, steep phase, resemble tall cone-shaped haystacks crowded together at the base (fig. 113). The hill rises to a fairly uniform height—approximately 200 feet. Fifty hills were counted on a typical 640-acre area. Not all the hills are cone-shaped, but the tendency is for them to become so. At present some hills are long and narrow, but the factors responsible for soil development gradually are separating the long narrow hills into two or more rounded ones. An average hill-side has from 3 to 6 inches of black granular calcareous clay loam or clay overlying a layer, a few inches thick, of gray friable clay loam and disintegrated limestone rock, which becomes more consolidated with depth. The surface soil is plastic when wet and rather dense and cloddy when dry. As the tops of the hills are cone-shaped, the depth of soil is less than on the slopes or at the bases of the hills. These hills are used almost entirely for pasture. They produce fair to good grass and are free from weeds, but from 1½ to 2 acres of pasture land are necessary to maintain an animal a year.

At the bases of some of the cone-shaped hills are small irregular-shaped flat valleys, most of them too small to indicate on the map. Most of the soil in the valleys is Camagüey clay and is very productive.

Areas of Soller clay loam, steep phase, occur between Corozal and San Sebastián, along the southern edge of the limestone area. This includes most of the cuesta, and there are few houses throughout the area of this soil.

Aguilita clay.—Aguilita clay is one of the extensive soils derived from soft limestone in the arid and semiarid southwestern part of the island. It occupies elevations ranging from sea level to more than 500 feet above, and the profile varies somewhat in depth, color, and

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FIGURE 113.—Vertical aerial view of area near Ciales. The steep cone-shaped hills in the lower right-hand corner consist of Soller clay loam, steep phase. The level area near the stream consists of Estación soils, and most of the soils in the top of the picture belong to the Colinas series. (Photograph taken by U. S. Navy.)

Vista vertical aére acerca de Ciales. Las colinas escarpadas cónicas a la derecha del frente son Soller arcilloso lómico, fase escarpada. La parte llana cerca del río consiste de suelos Estación, y la mayor parte de los suelos en la parte alta de la fotografía pertenecen a la serie Colinas. (Fotografía tomada por la Marina de EE. UU.)

FIGURE 114.—See legend on page 235.

organic-matter content from the arid to the semiarid areas. The native vegetation and land use also change with increasing rainfall. In all areas, however, rainfall is the limiting factor in crop production.

In an average location, this soil has a friable mellow granular calcareous dark grayish-brown clay surface soil 6 inches thick, which gradually changes to a friable mellow granular light-gray clay loam or clay subsoil about 8 inches thick. This layer rests on gray medium-soft porous limestone. In the drier areas the surface soil is shallower, contains less organic matter, is lighter in color, and in places has a distinct red tinge. In the areas of highest rainfall, the surface soil is nearly black and has a high organic-matter content, and the subsoil is yellowish brown. The depth of the profile varies with the degree of slope. Near the base of a long gentle slope, the thickness may be two or three times greater than on the steeper slopes. The relief of this soil ranges from undulating to rolling. In all places the soil is very sticky and plastic when wet, and when unprotected by vegetation it erodes rather readily during intense rains. The native vegetation in the arid section consists of cacti, thorny bushes, such as escambrón and Santa María, and bucare trees; in the semiarid sections the principal trees are almácigo, jagüey, and algarrobo; and the pasture grasses are guinea grass, Bermuda grass, and horquetilla, named in the order of their value.

This soil is correctly used as range land, and it requires from 3 to 7 acres to maintain an animal a year. During the wet season in all except the very dry areas 2 acres will furnish sufficient nutritious feed for an animal, but during the dry season the grass stops growing and a much larger acreage is required. The grass resumes growth within a few hours after the first heavy rain following a long dry spell.

In a few areas, closely associated with Yauco clay, sugarcane fields have been planted on this soil, but the average acre yields are only between 10 and 15 tons. The jibaros may plant a few acres to corn, cotton, tobacco, beans, and pigeonpeas, but the crops are often a failure except in favorable years.

Aguilita stony clay.—Aguilita stony clay differs from Aguilita clay in that it has steeper relief, more rock fragments on the surface, and a thinner surface soil. In many places these two soils are so interlaced that no attempt is made to differentiate them on the map. The stony soil has, as might be expected, low agricultural value and low carrying capacity. Only a very few acres are used for the production of subsistence crops (fig. 114).

The principal sources of income on areas of this soil are cattle and charcoal. The cattle graze on the planted guinea grass pasture lands.

FIGURE 114.—The brush-covered steep hills are nearly valueless Aguilita stony clay, and the level checker-board patterned irrigated sugarcane fields are San Antón soils valued at more than $700 an acre. Picture taken near Central San Francisco. The houses are located only along the main roads. The mean annual rainfall in this area is about 30 inches. (Photograph taken by U. S. Navy.)

Los montes cubiertos de maleza y de Aguilita pedrego-arcilloso valen poco y los campos de caña llanos y bajo riego son suelos San Antón valorados a más de $700.00 por acre. Fotografía tomada cerca de la Central San Francisco. Las casas están situadas solamente a lo largo de las carreteras principales. La lluvia en este sitio es alrededor de 30 pulgadas. (Fotografía tomada por. la Marina de los EE. UU.)

The charcoal is made from the wood of the slow-growing brush and trees. The raising of cattle is by far the most important enterprise, and there are many large cattle ranches. The close proximity to sugarcane fields makes the land especially valuable as pasture for oxen. The grass produced is highly nutritious, whether green or dry. The common practice is to clean the land of cacti and brush, then to plant guinea grass shoots in more or less well-defined checkrows about 2 feet apart. On this soil, the grass does not spread between bunches as it does in the valleys, where the supply of soil moisture is greater and the soils are deeper.

Aguilita stony clay, shallow phase.—The shallow phase of Aguilita stony clay is associated mainly with the typical soil, in areas west of Ponce. It not only is more shallow than the typical soil, but it is also more stony. In many places exposed rocks cover an area of several acres.

This shallow soil is characterized by a 1- to 5-inch grayish-brown, dark grayish-brown, or reddish-brown granular calcareous friable clay loam or clay surface soil, which rests on permeable limestone rock that allows rapid percolation of water and the penetration of grass and tree roots to a depth of several feet.

Practically all of this land is in brush and pasture, and it is considered of less value than Colinas stony clay loam, the soil it most closely resembles, because it occurs in areas of less rainfall and therefore brush and trees grow at a slower rate. Probably only about 50 percent of this shallow soil has been cleared and is in pasture; the rest is in trees and brush. Probably from 10 to 15 acres of pasture would be necessary to maintain an ox properly during the year.

Tanamá stony clay.—Tanamá stony clay is one of the most extensive soils. It occurs from Carolina to Aguadilla, a distance of more than 80 miles. It is derived from a limestone rock that consists predominantly of a series of massive reeflike beds alternating with the bedded chalky strata. In areas of this soil the pepinos, or cucumber-

FIGURE 115.—Brush-covered saw-toothed hills of Tanamá stony clay east of Manatí. Sugarcane on Bayamón clay in the foreground.

Colinas serradas cubiertas en maleza de Tanamá pedrego-arcilloso al este de Manatí. Al frente caña en Bayamón arcilloso.

shaped hills, are developed to a very great extent. In places they occur as long narrow east-west chains, such as those near Toa Baja and Vega Alta, and in other places they occur as wide belts of saw-toothed hills crowded together at the bases (fig. 115).

The surface soil of Tanamá stony clay consists of red or reddish-brown clay ranging in thickness from almost nothing to nearly 3 feet. Areas having the thicker surface soil are not common, and the average thickness is about 3 inches. The clay is underlain by hard limestone that weathers very slowly, producing a soil that is red and acid. The surface soil everywhere contains an abundance of angular limestone fragments, but the red soil material is slightly acid in the drier part of the island near Isabela and very acid in the eastern part near Bayamón.

Although the deeper areas of this soil are of irregular occurrence, none of them occurs on the hilltops. They may or may not occur on the lower slopes and near the bottoms of the numerous sinks in this general locality. This soil is very rugged and rough throughout all areas. The hills rise to fairly regular heights; the sinkholes in the intervening depressions are several hundred feet deep and range from a few hundred feet to half a mile in diameter. In some places a sinkhole occurs within another sinkhole. In many places the sinkholes are bounded by steep or even precipitous slopes. This soil is drained almost entirely by underground streams. Ríos Guajataca, Tanamá, Camuy, and Grande de Arecibo flow through deep canyons across areas of this soil. The Tanamá and Camuy Rivers are subterranean through parts of their courses. Water drains to the numerous sinks and disappears.

The soil is so rocky and rough that it is almost entirely nonagricultural, and most of the area is covered by brush and trees. After the virgin trees were cut the land was planted to crops, but yields were so low that the fields were abandoned and grew up to brush and trees. The principal industry on areas of this soil is the gathering of fuel wood and the making of charcoal. The amount of income obtained from an acre is difficult to determine, because only a few trees are cut at a time. If the trees are fairly dense, nearly 1,000 35-pound sacks of charcoal can be made from an acre. Considerable work and much time are required to make the charcoal. The trees most commonly used for the making of charcoal are ausubo, ortegon, guamá, guaba, moca, capá prieta, roble, Santa María, and moral. Some coffee, bananas, and plantains are grown, and usually near each house a fraction of an acre is under cultivation to yautias, sweetpotatoes, beans, and ñames.

Considering the roughness of the country there are many houses in this area, which are accessible only by foot and horse trails. All the products are carried out either on the heads of peons or on the backs of pack animals. The animals used are small hardy horses and mules that are raised on the island.

Ensenada clay.—Ensenada clay may be considered the Red Desert soil of Puerto Rico. This soil occurs in rolling or undulating areas (fig. 16) along the driest part of Isla de Vieques and on the mainland between Río Guayanilla and Bahía Montalva. It is derived from rather hard Tertiary limestone and is characterized by a 2- to 4-inch friable permeable softly granular reddish-brown neutral or alkaline highly colloidal clay surface soil. This is underlain by friable per-

meable brownish-red clay that rests on gray medium-hard limestone at a depth ranging from 6 to 12 inches. The color and depth of this soil vary greatly. Within rather small areas the surface soil may range from brown to red, and the depth above rock ranges from a mere film to 15 inches.

Owing to low rainfall, shallowness of the soil, and no feasible system of irrigation, this land is not suited to cultivated crops. Cacti, almácigo, jagüey, maguey, escambrón, and Santa María are the predominant tree and brush vegetation. Guinea grass will grow if it receives extra good care. More than 15 acres of this land are required to obtain sufficient feed for an ox a year. Goats do very well on this land, as they can live on the brush.

This soil is drained entirely by subterranean streams, and water for livestock and human beings is obtained mainly from wells operated by windmills in the valley on Fraternidad soils. A limited amount is obtained from the rainfall caught from the metal roofs of houses. Probably fewer people live on this soil than on any other upland soil on the island. Parts of the brush-covered areas are nearly impassable and have the appearance of a cactus desert and thorny brush jungle.

Ensenada clay, shallow phase.—The shallow phase of Ensenada clay is little more than bare limestone rock. It is closely associated with the typical soil, and in many places it is impracticable to separate the two on the map. Although both have low value, the shallow soil is the poorer. It is waste land or is used for the production of brush and trees. Such land adds very little to the value of a farm having some good land.

This soil has rolling or hilly relief, and most of the soil material, which is red permeable clay, is encased in pockets and crevices in the medium-hard limestone rocks. Trees growing from these pockets and crevices are slightly superior to those growing from the bare limestone. Many areas are devoid of both soil and vegetation.

Areas of this soil shown on the map with outcrop symbols are worthless as they consist almost entirely of limestone rocks and rock outcrops.

San Germán clay.—San Germán clay resembles Aguilita stony clay, except that it is derived from a harder and older limestone. This soil is developed on east-west ridges, intimately associated with volcanic rocks, in the southwestern corner of the island.

It is characterized by a dark grayish-brown granular mellow calcareous clay surface soil about 6 inches thick, underlain by friable porous brownish-gray calcareous clay loam or clay, resting on hard limestone at a depth ranging from 8 to 10 inches.

The subsoil is not so hard that plant roots cannot penetrate, therefore grass and trees grow equally as well as on Aguilita stony clay. The carrying capacity of the pastures is about 4 acres to an animal. Cows used for dairying as well as for the production of calves comprise most of the livestock. The male animals are used for draft purposes. Some small herds of sheep roam over this land, and nearly every jibaro farmer has a goat or a pig. Houses are not very numerous, as the soil is too shallow and the climate too dry for successful production of subsistence crops. Near the bases of the hills, especially on the north side, where the soil is deeper and the rainfall greater, a few

sweetpotatoes, beans, and pigeonpeas are produced during favorable years.

Nearly all of the areas of San Germán clay have some stones and rock fragments on the surface, but the stony areas shown on the map with stone symbols have many rock outcrops, the land is steeper than in other areas, and it is less valuable for the production of grass. Most of the stony land is covered with brush and trees.

Lajas clay.—Lajas clay is similar in many respects to Tanamá stony clay, but the two soils were differentiated, as the Lajas soil is derived from Cretaceous limestone. It differs from San Germán clay in that it occurs in areas having much higher rainfall. Therefore, the vegetation is more dense, the soils more acid, and the color of most areas is reddish brown.

Lajas clay is distributed in many widely separated small areas from Boquerón to Cayey. It is characterized by a reddish-brown, red, or brownish-red fairly plastic neutral or acid clay surface soil ranging in thickness from 1 to 8 inches. This is underlain by hard comparatively pure limestone rock. The relief ranges from hilly to precipitous, and in many places large areas appear as steep sharp brush-covered pinnacles devoid of soil.

In some places this soil has a nearly black surface soil, but the black and red soils are so intimately associated that no attempt is made to differentiate two separate soil series, although the darker soil probably contains more organic matter and is more plastic when wet than the areas of red soil. Vegetation grows equally well on both.

This soil is used for the production of trees and grass. It is slightly more desirable than Tanamá stony clay, as it occurs in more readily accessible areas. Goats thrive better than other livestock on the vegetation produced from this soil. Subsistence crops and tobacco are often planted in small local spots, many of which are not over 20 feet square. Yields are fair, as the rainfall is sufficient to prevent serious drought. The cutting of brush and trees for the making of charcoal is one of the principal enterprises on this soil.

Lajas clay, rolling phase.—The better areas of Lajas clay that occur on gently sloping or undulating relief are mapped as Lajas clay, rolling phase. This soil is much better than the typical soil, as it has a friable red clay surface soil 6 or 8 inches thick, underlain by an 8- or 10-inch subsoil of red permeable friable clay, which, in turn, rests on limestone. The combined thickness of the surface soil and subsoil is sufficient for the production of sugarcane and most cultivated crops, and, as the relief also is favorable, several areas are planted to crops. As this soil occurs in small areas, however, it is used mostly as pasture land in connection with the closely associated Lajas clay. Cerrillo and grama are the two principal grasses produced. The carrying capacity of the pastures is about 2 acres for an ox.

Most of this soil is in the vicinity of Lajas.

Jácana clay.—Jácana clay occurs on low foothills. It bears the same relationship to Descalabrado silty clay that Juncos clay does to Múcara silty clay loam. In most areas, the Jácana soils are similar to but better than the Descalabrado soils. This soil occurs in areas having less than 30-percent slope, and the surface soil consists of an 8-inch layer of friable irregular-shaped granular alkaline slightly plastic brown clay or silty clay. This layer gradually changes to dense medium-plastic alkaline yellowish-brown or light-brown clay,

8 to 10 inches thick, which grades through disintegrated rotten volcanic rock and rests on hard bedrock at a depth ranging from 15 to 40 inches, depending on the slope. The steeper the slope, the nearer the rock to the surface. In a few small areas, the subsoil is reddish brown.

This soil lies only in sections having low rainfall and is therefore used almost exclusively for pasture. Guinea grass probably occupies over 50 percent of its acreage. Such land would produce fair sugarcane if it were in areas of high rainfall. The carrying capacity of the pastures is higher than of those on Descalabrado silty clay. In most places 1½ acres will maintain an ox most of the year. Some minor crops are produced during favorable years. Corn yields about 600 pounds to the acre and Japanese sugarcane produces from 10 to 15 tons without irrigation or much fertilizer.

Many areas of this soil lie northeast of Parguera.

Descalabrado silty clay.—Descalabrado silty clay and its phases are the most extensive soils south of the Cordillera Central. The surface soil of Descalabrado silty clay consists of a 6-inch layer of semigranular friable alkaline silty clay or clay, which ranges in color from light brown in the arid and semiarid areas to very dark grayish brown in the subhumid areas. The material in this layer grades rather abruptly into slightly decomposed fragmental tuff or tuffaceous shales containing free lime carbonates, especially along the long slender seams in the rocks. The rock becomes harder and more alkaline with depth. This rock is not too hard, however, for the roots of trees and grass to penetrate for a supply of moisture and plant nutrients.

This soil lies almost entirely on slopes ranging from 30 to 60 percent, and nearly all of it is used as pasture and brushland. Many large cattle ranches are located on it. After the brush and cacti are cleared and guinea grass is planted, this land makes excellent pasture during the rainy periods, and at that time supports about one head of livestock to the acre. During long dry periods, however, the grass dries, and starvation of many head of livestock pastured on this soil is not uncommon.

This soil occurs on the islands of Vieques and Culebra and is extensive near Cabo Cabezas de San Juan and between Sabana Grande and Patillas.

Some variations exist within certain areas of this soil type. In places the subsoil is red or reddish brown, and even the partly disintegrated rocks have a coating of red or reddish brown. In areas that join the Múcara soils, the surface layer is much darker than the average because of the high mean annual precipitation. On the concave slopes of the areas having a higher rainfall, the soil is more acid, deeper, and slightly more red than is typical, and such areas are sometimes used for the production of coffee and bananas.

Descalabrado silty clay, rolling phase.—Areas of Descalabrado silty clay that have a slope of less than 40 percent are differentiated as a rolling phase. The two soils are so intimately associated that many areas of the rolling land probably are included on the map with the typical soil. Both soils are used almost entirely for pasture and forestry, but the rolling soils have a higher carrying capacity, higher value, and higher proportion of grass to trees. Large areas of this soil occur in the low foothills south of Sabana Grande, near Coamo,

and near Juana Díaz. East of Guayama an area including some low nearly flat hills has been included in mapping. This area is not extensive and differs from the typical soil, in that the soil above rock in few places is more than 4 inches thick, and in some places bedrock is exposed. This included area is used only for pasture.

Descalabrado silty clay, shallow phase.—The shallow phase of Descalabrado silty clay differs from the typical soil, in that it is slightly more broken in relief and is shallow, due to more severe erosion. This soil occurs on steep knifelike-edged ridges and slopes where the annual rainfall ranges from 55 to 65 inches. It occupies large areas north of Yauco, near Rincón, and south of Sabana Grande. In many places the parent lime shale and calcareous tuffaceous rock outcrop on the tops of the ridges and on the sides of hills.

The soil, to an average depth of 8 inches in a cultivated field, is characterized by a grayish-brown or brownish-gray friable semigranular alkaline silty clay or silty clay loam surface soil that has considerable rock fragments intermingled with the soil particles. In most places the surface soil does not rest on solid rock but gradually changes to partly disintegrated rock, which, in turn, changes to solid bedrock below. The thickness of the surface soil ranges from 4 to 8 inches on the ridge tops and from 8 to 14 inches on the slopes. In areas that have never been cultivated, the surface soil is much thicker and darker than in cultivated fields.

This soil is shallow, steep, and not very productive for cultivated crops. In most countries it would be used only for pasture, but the ever-increasing pressure of population demands the cultivation of such soil. The rainfall on this soil is sufficient to tempt the peons to plant clean-cultivated crops, such as corn, beans, pigeonpeas, yuca, and some tobacco, but it is not sufficient for the rapid growth of plants. When the rainy season begins, the intense rains erode the soil before the vegetation has a chance to retard the flow of water. The extent of erosion is not so great as in the clean-cultivated mountainous areas of some of the tobacco districts, but the harm resulting from the erosion is more lasting. When this soil becomes so unproductive that it is abandoned, small gullies appear before the slow-growing pasture grasses can become established to the extent of combating the onslaught of the dashing rains. This land erodes severely for a year or two, but finally the grass thickens and erosion is arrested. After a long time the land builds up to some extent and is again cultivated, the gullies and catsteps are smoothed over, and the fields present a fairly good appearance.

This soil becomes eroded if it is overpastured, thereby reducing its yearly carrying capacity from 2 acres to 3 or 4 acres for an animal. The best measures now used for the prevention of erosion are crudely constructed brush terraces (fig. 116) and hedgelike strips of guinea grass planted with the contours. More than 50 percent of this soil is in cultivated crops, and the remainder has been in crops at one time or another.

Descalabrado silty clay, eroded phase.—Descalabrado silty clay, eroded phase, is closely associated with Descalabrado silty clay, shallow phase. The difference between the two soils is in their relief. The largest areas of the eroded soil occur in the vicinity of Rincón on slopes of less than 60 percent. This soil is less extensive than Descalabrado silty clay, shallow phase, but it is slightly more desirable, and a

higher proportion of it is in cultivated crops. About 50 percent of it is used for pasture and 50 percent for subsistence crops.

The yearly acre yields of crops on this soil are as follows: From 200 to 300 pounds of pigeonpeas, from 5 to 7 bushels of corn, from 250 to 300 pounds of beans, and from 1,000 to 1,200 pounds of yautias. Often sugarcane is planted on this soil along the highways near a sugar central, but it seldom yields more than 8 or 10 tons an acre, and the crop is difficult and expensive to cultivate and harvest. Sugarcane and yautias are much better for preventing soil erosion than the other cultivated crops.

During dry years yields are low, as the soil is so shallow that it has very low water-holding capacity. Beans and corn often produce little or nothing during very dry years. Drought is more destructive on the ridges than near the bases of the hills, where the soil is deeper and better.

FIGURE 116.—Brush terraces on a steep slope of Descalabrado silty clay, shallow phase, north of Yauco. Erosion is very severe in this district. The annual rainfall is sufficient to tempt the jibaros to plant clean-cultivated crops, but not enough for rapid growth of plants, therefore the water runs the full length of the hill unchecked unless brush terraces are built. (This photograph was taken during a rather heavy rain.)

Bancales de maleza hechas en una ladera escarpada de Descalabrado limo-arcilloso, fase poco-profunda, al norte de Yauco. La erosión es muy fuerte en este distrito. La lluvia anual es suficiente para tentar a los jíbaros a sembrar cultivos que requieren desyerbo, pero como la lluvia no es suficiente para el crecimiento rápido de las plantas, el agua corre a todo lo largo del monte desenfrenadamente, a menos que se hagan bancales de maleza. (Fotografía tomada durante una fuerte lluvia.)

Nearly all the work done on this soil is performed by hand. The population on areas of this soil is very dense. Probably more than 600 people to the square mile obtain an existence from the subsistence crops they grow, supplemented with the wages they receive for part-time work at sugar centrals or for needlework.

Guayama clay.—Guayama clay is readily differentiated from the other soils of the semiarid uplands derived from volcanic rocks by its red color, which is visible for a quarter of a mile or more, especially on

the southern slopes of the hills, where it is more intensified, owing to greater dehydration of the soil.

With the exception of its color, this soil is similar to Descalabrado silty clay. It seems to be derived from a hard greenish-blue volcanic rock that contains some free lime on freshly exposed surfaces and probably has a rather high iron content.

In a virgin area this soil is characterized by a 5-inch dark brownish-red or reddish-brown friable alkaline granular clay or silty clay surface soil, which is abruptly underlain by light-red fairly compact fragmental plastic clay, alkaline in reaction and in few places more than 6 inches thick. At a depth of about 11 inches the soil material is brown or light reddish-brown friable gritty clay loam containing many rock fragments in the process of weathering. This layer rests on bedrock at a depth ranging from 8 to 28 inches, depending on the slope. The rougher and steeper the relief, the thinner and less valuable is the soil for its principal uses—pasture and forestry.

This soil occurs in several widely separated areas, each having a slightly different land use. The largest two bodies cover the steep hills north of Guayama and near the center of the Isla de Vieques. Both are used for pasture. The area occupying the long high rounded east-west ridge west of Parguera is the driest part of this soil and, therefore, has the most scant vegetation, which consists of thorny brush, cacti, almácigo trees, weeds, and a small proportion of planted guinea grass. The soil on the eastern end of the ridge is slightly acid and resembles Yunes clay in many respects. In many places this area contains reddish-green chips of rocks averaging about 3 inches in diameter. The rocks are of many sizes, however, including some rock outcrops. In many places the soil is not more than 3 inches thick above a bed of rock fragments, soil, and large rocks.

The area near Ceiba receives sufficient rainfall for mediocre yields of sugarcane or subsistence crops. This area differs from average Guayama clay in that it has a thicker more acid surface soil and subsoil, probably due to a higher rainfall. This area, as well as areas on Isla de Vieques and elsewhere, have many siliceous rocks on the surface and some outcrops.

Areas of this soil shown on the map with stone symbols are steeper, stonier, and poorer than the typical areas and are, therefore, less valuable for all crops.

Guayama clay, colluvial phase.—The colluvial phase of Guayama clay is very similar in many respects to typical Guayama clay. It differs from that soil in that it has a deeper surface soil and subsoil. It is intermediate in physical and chemical characteristics between Machete clay and Guayama clay.

This soil is characterized by an 8- or 10-inch reddish-brown neutral heavy clay granular surface soil underlain by a brownish-red heavy granular clay subsoil, about 14 inches thick, which rests on partly disintegrated greenish-blue rock. This soil has gently sloping relief, and some areas are irrigated and produce from 60 to 75 tons of sugarcane to the acre. Most of the land, however, is nonirrigated and produces guinea grass for the oxen used as work animals on the nearby sugar centrals. This soil occurs in the vicinity of Guayama, where the rainfall is not sufficient to insure profitable yields of subsistence crops.

Daguao clay, steep phase.—Daguao clay, steep phase, is similar to some of the soils of the southern prairies in the United States. It

occurs in areas of steep relief in the eastern end of the island where the mean annual rainfall is between 65 and 70 inches. It is readily identified by its nearly black surface soil and reddish-brown compact subsoil.

The 6- or 8-inch surface soil is very dark grayish-brown or nearly black neutral plastic granular heavy clay that cracks greatly when dried. This layer abruptly changes to reddish-brown, or brown with a red tinge, compact plastic dense clay, 8 to 10 inches thick, which grades into disintegrated greenish-black alkaline rock fragments resting on solid rock at a depth ranging from 20 to 40 inches, depending on the slope.

Most of this soil has been cultivated at some time, but experience has shown that the moisture reaching the roots of plants is not sufficient to produce a profitable crop except in very wet years, and now most of the soil is used as grassland, for which it is exceptionally well adapted. The carrying capacity of the pastures not only is high, but the livestock feeding on the grasses have firm, hard fat.

Múcara silty clay loam, steep phase.—Areas of Múcara silty clay loam that occupy slopes ranging from 60 to 80 percent are differentiated on the soil map as a steep phase of Múcara silty clay loam. This steep soil is so interlaced with the typical soil that in many places the boundary between the two is drawn arbitrarily. The steeper soil consists of a thin layer of soil and rock fragments over massive tuff or other Upper Cretaceous rocks.

This soil occurs over an area having an annual rainfall ranging from 65 to 80 inches. The amount of moisture retained by the soil depends to a great extent on the degree of slope, and it is reflected by the acidity and color of the soil. The smoother the slope the greater the content of soil moisture, therefore the lower the pH value and the grayer the soil.

The surface soil, which in few places is more than 8 inches thick, ranges from silt loam to heavy silty clay loam that may be grayish brown, dark grayish brown, or very dark grayish brown, depending on the amount of soil moisture received. When wet, the material feels velvety and slightly plastic. This layer grades into a broken mass of partly disintegrated yellowish-brown shale and tuff fragments resting on bedrock. The depth of this soil on the ridge tops ranges from 4 to 8 inches and on the lower slopes from 8 to 14 inches.

This soil occurs in large areas near Cayey as well as in many other places. Practically all the land is cleared of brush and trees and is used for pasture. The carrying capacity of this land is about 2 acres for an animal. The grass has sufficient strength to produce a firm good-quality beef, but it is not so good as in areas having less than 45 inches of annual rainfall on similar soils. A few farmers attempt to grow tobacco and subsistence crops on the steep slopes, but yields are low, and the land is seriously damaged by sheet erosion.

Areas of this soil south of the Cordillera Central crest in the lower rainfall district have a much darker surface soil than the average for this soil. This is especially true in virgin areas where this soil grades into the Descalabrado soils. Such areas are planted to coffee or are in pasture. The yield of coffee is low, and the crop may be harmed by leaf spot. The grass produced is exceptionally good, in both quality and quantity.

Múcara silty clay loam, shallow phase.—Areas of Múcara silty clay loam, shallow phase, might be called steep mountainsides, as they include all areas of the Múcara soils that have slopes greater than 60 percent, and some are more than 120 percent. This soil occupies many high Λ-shaped ridges that are separated by V-shaped canyons, some of which are 1,000 feet deep.

The soil, as may be expected, is thin, rocky, of low value for cultivated crops, and adapted only to trees and grass. Any cultivation of this soil causes erosion, as, when the land is plowed, the clods roll down the hill by gravity and much soil is lost through the action of water. At one time large areas were planted to coffee, which produced fair yields, but recently the coffee and shade trees have been cut. Crops are planted even on 90-percent slopes, but they are not profitable, and the land soon grows up to grass. It produces fairly good pasture, but the soil is too thin for the production of coffee.

Múcara silt loam, steep phase.—Múcara silt loam, steep phase, differs from Múcara silty clay loam, steep phase, in that it has a lighter textured, slightly more acid, and more friable surface soil. All other characteristics are the same, and the land use of the two soils is similar. Both are used extensively for pasture and to less extent for subsistence crops.

This soil occurs in the western part near Añasco and in the west-central part near Utuado. Around nearly every hut is a small area used for the growing of sweetpotatoes, beans, and pigeonpeas. All crop yields are low, but the soil is more desirable than the Yunes or Tanamá soils.

Picacho stony clay loam.—Picacho stony clay loam occurs on very steep hills (fig. 5) and low mountains in the high-rainfall areas of the interior. It is derived mostly from igneous rocks, most of which are andesitic in composition, and partly from hardened shales and conglomerates. The surface soil is characterized by light grayish-brown plastic silty clay loam, clay loam, or clay. The texture is variable, depending on the decomposition of the parent rock, which depends on the rainfall. In the highest rainfall areas and at the heads of drainageways, the surface soil is clay, but on very steep hillsides that have only a thin surface soil only partly decomposed, the texture is gritty clay loam. Beneath the surface soil, which averages about 4 inches thick, is a mixture of partly decomposed rock fragments, yellowish-brown or reddish-brown clay material, and hard rock, resting on the unconsolidated parent material at a depth ranging from 3 inches on the steep slopes to 14 inches at the bases of the hills or along colluvial slopes adjacent to small natural drains. This soil is acid and extremely rocky.

Owing to the high content of stones, unfavorable relief, and shallowness, the land seldom is used for cultivated crops. Because of the high rainfall and comparatively high content of organic matter in the surface soil, coffee produces from 100 to 400 pounds on the best areas. Probably 80 percent of the land is in pasture or forest, the acreage of the two being about equally divided. Charcoal is one of the principal products of the forests. A 35-pound sack of charcoal sells for 10 cents on the farm and about 15 cents when transported to the cities. It is very difficult to estimate the amount of charcoal produced to the acre, as only a few trees are cut each year. Grass grows luxuriantly, but it

is inferior in quality to that produced on the Descalabrado and related soils in the semiarid and arid sections.

Naranjito silty clay loam, steep phase.—Areas of Naranjito silty clay loam that have a relief greater than 60 percent are differentiated as a steep phase. This soil and the typical soil are intimately associated and occur in small areas throughout the interior near Orocovis and Ciales, and elsewhere.

The 6- or 8-inch surface soil consists of light grayish-brown single-grained acid plastic silty clay or clay. It is underlain by plastic clay ranging in color from gray to reddish brown and is streaked with brown, yellowish brown, or red. This layer rests on parent rock, at a depth ranging from 8 inches on steep slopes to 20 inches on long gentle slopes.

This soil is used extensively for pasture and to less extent for tobacco, subsistence crops, and coffee. It is not so desirable a soil as Múcara silty clay loam, steep phase, as it receives more rainfall, is more acid, and is leached to a greater extent. It is also more plastic and harder to cultivate. Lime and fertilizer would benefit this soil for use in the production of crops as well as for pasture.

Yunes clay.—Yunes clay is geologically related to the Río Piedras soils, but it is shallower and may be considered almost a shallow phase of Río Piedras clay. It has a gray or light grayish-brown shallow clay surface soil, which is underlain by a yellowish-brown plastic shallow subsoil overlying fragmental shales. The shales occur at a depth ranging from 6 to 16 inches, depending on the slope. The material in all layers is very acid. The soil appears nearly white from a distance.

This soil occurs on the steepest of the shale hills that are west of Carolina and extend almost to Utuado. A few areas are near Peñuelas. Most of the land is either in pasture or trees. About 2 acres are required to pasture an animal. If the land is cultivated, yields are low. If the forests are cut and the land is planted immediately to sugarcane, yields range from about 20 to 25 tons to the acre the first year or two, but they soon decline to 12 to 15 tons.

Yunes silt loam.—Yunes silt loam is similar to Yunes clay, except in the texture of the surface soil. Most of the silt loam occurs in the eastern part of the island near Fajardo. It is used for the same crops as is the clay. In areas having a rainfall of less than 45 to 50 inches, this soil develops a cemented layer at a depth just above bedrock. This is especially noticeable from Fajardo toward the Fajardo lighthouse. This layer does not interfere with the growth of either grass or trees, but it would seriously affect cultivated crops.

Mariana clay loam.—The surface soil of Mariana clay loam, to a depth of 6 or 8 inches, is pale-gray or yellowish-gray strongly acid clay loam or silt loam, which is friable, fluffy, and powdery when dry but sticky and plastic when wet. This layer is underlain by intermingled rock fragments, soil particles, and roots. In many places the average depth to bedrock is less than 10 inches, and many hilltops are capped with large irregular-shaped black and reddish-brown rocks.

This soil covers many small areas from a point near Daguao in the eastern end of the island to a point near Lajas in the southwestern part. It occupies slopes ranging from 40 to 80 percent.

This is considered a poor agricultural soil by most farmers, but the areas planted to pineapples near Lajas produce very good yields.

Juana Díaz clay loam.—The 6-inch surface soil of Juana Díaz clay loam is dark grayish-brown granular medium-plastic neutral or alka-

line clay loam. It is underlain by a 6- to 10-inch subsoil of brown prismatic medium-compact neutral or alkaline silty clay loam. The substratum, which continues to a depth of more than 6 feet, consists of friable yellowish-brown fine-grained sandstone, with many rounded pebbles and water-worn rocks. Thin seams and small splotches of soft lime carbonate deposits are common.

This soil occurs on rolling or steep hills in the vicinity of Juana Díaz. It is used most extensively for pasture, but a few acres annually are planted to subsistence crops and tobacco. The mean annual rainfall in few places exceeds 45 inches, and crop yields are low. The soil has about the same value for pasture as has Jácana clay. In some places the surface soil is very thin or is absent, and here and there the parent material is exposed by erosion.

Juana Díaz silty clay.—Areas of Juana Díaz silty clay are closely associated with Juana Díaz clay loam, but in most places they occupy the lower, smoother slopes. The silty clay occupies only a few hundred acres in the vicinity of Juana Díaz.

The surface soil consists of an 8- or 10-inch layer of light-brown coarsely granular plastic alkaline silty clay that changes abruptly to reddish-brown compact prismatic plastic clay having an average thickness of 5 inches. This layer rests on yellow friable alkaline clay loam or sandy clay loam that gradually changes to rotten very fine grained sandstone parent material containing considerable soft lime deposits.

This soil is used more extensively for cultivated crops than is Juana Díaz clay loam. A few areas are planted to sugarcane, which yields from 40 to 45 tons to the acre when the land is properly fertilized and irrigated.

Rosario silty clay.—Comparatively speaking, Rosario silty clay resembles a shallow phase of Nipe clay. It occurs on 40- to 180-percent slopes from Mayagüez to Yauco, and serpentine rock lies within a few inches of the surface.

The 2- to 4-inch surface soil consists of friable granular permeable nonplastic purplish-red neutral silty clay that grades into partly weathered serpentine rock at a depth ranging from 4 to 10 inches. Below this material is the green flaky foliated serpentine rock, which feels soapy and polishes readily when rubbed with the hand. During decomposition the topmost flaky rock weathers almost completely before the chemical weathering process starts to decompose the adjoining layer.

This is one of the poorest soils, owing not only to its unfavorable relief and shallowness but to the lack of plant nutrients in the soil material and parent rock. The soil contains considerable chromium and nickel, which probably have a toxic effect on plant roots, thereby reducing the growth of plants.

Most of this land is used for forest. Coffee is grown on the concave slopes, where, through the additional organic matter and water, fairly productive trees are maintained.

This soil is more droughty than soils of the nearby hills derived from tuff and limestone. Cacti and thorny desertlike shrubs are the predominant vegetation on many acres after the virgin timber has been cut. A few acres in virgin timber were noted south of Maricao in the national forest. The trees are small for their age and do not have a healthy appearance. The mat of vegetation covering the soil in virgin areas is 6 to 8 inches thick, very spongy, and light in weight.

Many landslides occur on this soil after unusually heavy tropical rains. Most spots affected by slides are not over 20 feet wide, but some are from 50 to 100 yards long. The foliated slippery character of the serpentine causes the rocks to slide over one another and carry the shallow soil mass with them down the slopes.

Several mineral springs rise in areas of this soil, and the water is exceptionally good for drinking purposes. Very few people live on this land, and the general appearance of the country is exceptionally poor.

The Polytechnic Instituto at San Germán is located on this soil, and by applying large quantities of fertilizer and irrigating, fair yields of guinea grass and minor crops are produced from small acreages.

Rosario silty clay, smooth phase.—Rosario silty clay, smooth phase, differs from the typical soil in that it has smoother relief, is much less red or purple, and occurs in more arid sections. It is characterized by a brown or light-brown friable semigranular silty clay surface soil 5 or 6 inches thick, underlain by a red or brownish-red permeable clay subsoil from 4 to 6 inches thick. This layer rests on partly disintegrated serpentine rock. In most places the depth of soil above the rock ranges from 2 to 12 inches, depending on the slope, but in some places the parent rock is exposed.

This soil occurs in many small irregular-shaped areas where the mean annual rainfall is less than 65 inches. The largest bodies are between Yauco and Sabana Grande and near San Germán. This soil is used only as brush and pasture land. Neither brush nor grass grows very rapidly or becomes very dense. The boundary line between this soil and the adjacent soils is everywhere extremely sharp and can be detected by the vegetation which in few places on this soil is one-third as good as that on the other soils.

Vieques loam, steep phase.—Vieques loam, steep phase, occupies steep hills in the granitic part of the western end of Isla de Vieques and the northern part of Isla de Culebra.

It is similar to Pandura loam, but it occurs in a much drier climate and is more alkaline in reaction. It is used almost entirely for pasture and is considered less desirable than Descalabrado silty clay or Guayama clay for quality and quantity of grass produced. A few banana plants are grown near the jibaros' homes.

This soil is characterized by a very dark grayish-brown friable gritty loam surface soil 6 to 8 inches thick, underlain by an 8- to 10-inch layer of reddish-brown firm but gritty sandy clay loam resting on partly disintegrated coarse-grained granite at a depth ranging from 12 to 20 inches, depending on the steepness of the slope. Large rounded blocks of granite are scattered over the surface.

Rough stony land. Rough stony land includes areas too rough and broken or too stony for the cultivation of crops. In many places it consists of the high jagged wind-swept moss-covered mountain peaks at elevations above 3,000 feet. In average areas, such trees as sierra palm, treeferns, llagruma, granadillo, and tabonuco are the most conspicuous. Some of the virgin timber is still standing on the most inaccessible areas (fig. 117). The growth of vegetation depends more on climatic conditions than on soil. For example, on the highest peaks of the Sierra de Luquillo the wind is so severe that the trees are dwarfed and have crooked interlacing limbs, and the nearly continuous mist and rain are more favorable for mosses and ferns than for nutritious

grasses. The soil material of this type of land, in the numerous areas of its occurrence, includes many variations in texture, color, consistence, and structure. In most areas it consists of a thin layer of dark grayish-brown or grayish-brown plastic acid clay containing an abundance of leaf litter, moss, roots, and sharp angular rock fragments. This layer rests on hard rocks. At the heads of drainageways or near springs and watercourses, the soil is deep-gray plastic acid waterlogged clay, with many rusty-iron stains at a depth ranging from 16 to 20 inches.

In some spots, the soil is red, permeable, and deep, and in other places the stones are so numerous that a person can travel for a distance of half a mile by stepping from stone to stone. A large area of soil derived from granite, occurring in the vicinity of Pico Este, is

FIGURE 117.—Rain-forest vegetation on rough stony land. The mean annual rainfall exceeds 120 inches.

Bosque en tierra pedregosa quebrada. La lluvia anual excede 120 pulgadas.

included with this land type. This area has a light-colored gritty loam, sandy clay loam, or sandy clay surface soil 3 or 4 inches thick, underlain by a thin light-gray or ash-gray bleached strongly acid silty layer, which, in turn, is underlain by a thin iron crust or a rusty-brown or reddish-brown friable layer high in iron. This material gradually changes to loose gritty friable sandy loam and partly disintegrated quartz diorite rock.

This type of land is best used for its scenic beauty. The many rapids, cascades, and beautiful waterfalls, the cool and invigorating temperature, the rain forest and moss vegetation, precipitous cliffs, and gorgeous views make these areas equal or superior to some of the national parks in the United States.

SOILS OF THE INNER PLAINS

Most of the soils of the inner plains include the low, gently rolling or nearly level valleylike areas between the mountains and the hills adjacent to the coastal plains or within the mountains that have deep plastic residual soils. With very few exceptions these soils have dark

sticky plastic heavy clay surface soils and deep plastic heavy subsoils. The soils are very retentive of moisture, but they are very difficult to plow or cultivate. If a soil auger is bored into the subsoil of most of them, even after a long dry period, the material is still moist and plastic and will stick tenaciously to the auger. Plant roots can penetrate the subsoil and substratum readily and remain in good condition during an average dry period. In a few places artificial drainage is necessary, and careful management is essential everywhere. If the soils of the inner plains are not plowed at about the right moisture content, large, dense clods are formed, which require many dashing rains to slake into fine granules. The surface soil may become dry during long, rainless periods, and cracks 2 inches wide extend to a depth ranging from 10 to 18 inches. This cracking is injurious to the upper roots of the plants, as many of them are stretched and severed by contraction of the soil. The lower roots, however, generally are in good condition.

Most of the soils in this group have a high organic content in the surface soil and are better adapted to sugarcane than to any other crop. Probably more than 80 percent of their total area is planted to sugarcane, and most areas are within economical hauling distance to sugar centrals. Coffee does fairly well on the well-drained sloping areas in the humid sections, but none is planted in the arid sections. Corn grows very well on these soils and is often planted on areas not irrigated or not readily accessible by oxcart roads. These soils are very poor for the production of citrus fruits, as internal drainage is too poor and the heavy plastic subsoils allow insufficient aeration. The few grapefruit orchards planted on some of these soils in the humid sections are growing fairly well on the well-drained convex slopes, but those planted on concave slopes or on level areas are very poor and probably will soon be replaced with sugarcane.

The soils of the inner plains include 29 soil types and phases of the Las Piedras, Mabí, Moca, Dominguito, Río Arriba, Santa Clara, and Camagüey series of the humid sections, and the Yauco, Ponceña, Portugués, Mercedita, Barrancas, Pozo Blanco, Amelia, Río Cañas, and Cabo Rojo series of the arid and semiarid districts.

To facilitate descriptions of the soil types, the soil series having similar parent materials are grouped and briefly described.

The Las Piedras soils are the only ones in this group that are derived from granitic materials. They are somewhat similar to the Cayaguá soils, except that they occur on undulating or nearly level moderately eroded peneplains at an elevation of about 500 feet. They are well-drained fairly deep warm acid soils requiring considerable fertilizer. They are used for tobacco, sugarcane, minor crops, and pasture.

The Mabí soils are the only ones derived from tuffaceous rock in the humid section. They are very similar to the Juncos soils. They occur on long gentle slopes or in nearly level areas in close association with the Juncos and Múcara soils. The elevation of the Mabí soils ranges from 10 to 1,000 feet above sea level. These soils have fair drainage and high fertility, are neutral or alkaline in reaction, and are rather hard to plow or cultivate. They are used almost entirely for the production of sugarcane, which yields very well.

The Moca, Dominguito, and Río Arriba soils are closely related to one another. Apparently they are derived from lower Tertiary shales

and clay. They occur at elevations ranging from 250 to 1,000 feet. They have plastic, acid, heavy surface soils and mottled red, gray, and yellow, plastic, sticky, acid subsoils, which grade into a more friable, acid, gravelly, mottled red, gray, and yellow substratum that also is very plastic when wet. The Moca soils have grayish-brown or brown surface soils. They occur mostly in the north-central part of the island, intimately associated with the Colinas soils. The Dominguito soil occurs in the west-central part, and it has a nearly black surface soil. The Río Arriba soil occurs in the eastern part, and it has a light-gray or light yellowish-brown surface soil. All these soils have undulating or rolling relief, and nearly all of their area is used for sugarcane, coffee, and minor crops. The yields of sugarcane range from fair to good. Coffee yields are fair, and yields of most of the minor crops are very good.

The Santa Clara and Camagüey soils of the humid section of the Yauco, Ponceña, Portugués, Mercedita, and Barrancas soils of the arid and semiarid sections are derived from calcareous materials, mostly limestone and calcareous shales. These soils occur at elevations ranging from 10 to 1,000 feet. They have dark grayish-brown or nearly black, plastic, waxy, alkaline or calcareous surface soils and yellowish-brown sticky, plastic subsoils overlying soft, gray limestone at various depths, depending on the soil series. Generally external drainage is adequate, as most of these soils have sufficient slope for the excess water to drain out. Internal drainage, however, is slow, and on level areas artificial drainage is essential.

These soils are fairly high in organic matter, bases, and plant nutrients, but when cultivated continuously to sugarcane they need commercial fertilizer applied at the rate of about 700 pounds to the acre a year. Most of these soils occur in fairly large uniform areas that can be conveniently managed with modern machinery, and if the mean annual rainfall is greater than 70 inches or if irrigation is practiced, nearly all of the land is planted to sugarcane or is in the process of preparation for that crop. Nonirrigated areas in the arid sections and inaccessible areas in the humid sections are used for pasture, corn, and minor crops. All crops produced on these soils seem to have a high nutritive value.

Salt is a limiting factor in only a very small part of the total area of these soils. Lime chlorosis greatly reduces the production of sugarcane, especially ratoon crops, on nearly all spots in the arid sections where limerock is exposed or lies within 6 inches of the surface. Lime chlorosis is not serious, except for pineapples, in the humid sections, even on bare limestone rock.

The boundary line between many of these closely related soils is drawn arbitrarily in many places. The main distinction between the Santa Clara and Camagüey soils is in the color of the surface soil, which is nearly black in the Camagüey and dark grayish brown in the Santa Clara soils. These soils differ from the Ponceña and Yauco soils in that they occur in areas having from 65 to 110 inches of annual rainfall and therefore are slightly less alkaline and more leached than the Ponceña and Yauco soils, which occur in areas receiving from 30 to 65 inches of annual rainfall. The Yauco soils bear the same relation to the Santa Clara that the Ponceña do to the Camagüey.

The Portugués soils differ from the Ponceña in that they are more calcareous and the limestone rock lies at slighter depth. The Mer-

cedita soils differ from the Portugués soils in that they are derived more from alluvial material washed from the nearby limestone hills and less from residual material.

The Barrancas soils differ from the Mercedita soils in that they have a darker surface soil and occur in long narrow strips adjacent to streams.

The Pozo Blanco soils are derived from material washed from medium-hard limestone. They are reddish brown and fairly friable. They occupy small valleylike positions in the most arid section of the island. These soils are well drained, granular, and very productive if the rainfall is sufficient. Most plants except the xerophytes, however, suffer from drought. A very small proportion of these soils is irrigated, and nearly all areas are used for corn, minor crops, and pasture.

The Amelia and Río Cañas soils are derived from tuffaceous rocks and shales. They occur on long gentle slopes or in valleylike positions at elevations ranging from 250 to 500 feet. These soils are closely associated and somewhat similar to the Jácana and Descalabrado soils, but they are much deeper and more fertile and have smoother relief. They are granular and are brown, dark brown, or nearly black, depending on the annual rainfall received—the greater the rainfall the darker the color. Parent rock lies at a depth ranging from 26 to 36 inches, depending on the slope.

The Amelia soils differ from the Río Cañas soils in that they do not contain free lime, whereas the latter soils have an abundance of lime carbonate below a depth ranging from 15 to 20 inches.

Very small areas of the Amelia soil are situated so that they can be irrigated economically; therefore they are used for pasture and tobacco.

The Cabo Rojo soils are similar in physical and chemical characteristics to the Río Arriba soils, but they occur in a semiarid section, and for this reason the land use of the soils of the two series is somewhat different. Most areas of the Cabo Rojo soils are in pasture or planted to the Uba variety of sugarcane. These are very poor soils that have been affected seriously by both sheet and gully erosion. They occur only in the southwestern part of the island.

Las Piedras clay loam.—Las Piedras clay loam is derived from quartz diorite. It occurs in gently rolling or undulating areas of the moderately eroded peneplains in the vicinity of Las Piedras.

This soil is characterized by a gray or somewhat reddish-gray friable nearly structureless acid clay loam surface soil that ranges in thickness from 4 to 12 inches. This layer is underlain by medium-compact light yellowish-brown acid clay that is fairly plastic when wet and in places is mottled with pink, orange, and bluish-gray splotches. The layer ranges from 2 to 10 feet in thickness. It rests on the disintegrated friable quartz diorite, which in turn grades without any definite line of demarcation into the unconsolidated parent rock.

Las Piedras clay loam is not a very productive soil without the use of amendments high in nitrogen and phosphorus, as it is derived from materials low in plant nutrients and also has been leached to a great extent. This soil, however, occurs in rather large uniform tracts that can be farmed easily with modern machinery, in a section of comparatively high rainfall. It is used extensively for the production of tobacco and sugarcane. During the years 1935 and 1936, when the

acreage in sugarcane was curtailed, many areas of this soil were idle or were producing pasture grass. Sugarcane on this soil produces from 25 to 35 tons of gran cultura when the land is properly fertilized and managed.

Las Piedras clay loam, steep phase.—A steep phase of Las Piedras clay loam lies adjacent to the few U-shaped drainageways that traverse areas of the typical soil. This soil differs from the typical soil not only in relief but also in its thinner surface soil. The parent rock is nearer to the surface in the steep areas. Nearly all of the land is used for pasture, the carrying capacity of which is fairly good. In most places 1 acre will pasture an animal throughout the year. Malojillo grass grows fairly well, especially in the bottoms of the drainageways.

Las Piedras loam.—Las Piedras loam is closely associated with Las Piedras clay loam and the other soils derived from granite in the east-central part.

The 6- or 8-inch surface soil consists of grayish-brown coarsely granular acid friable loam, which is underlain by olive-drab or reddish-yellow acid medium-compact clay loam. This layer is underlain at a depth ranging from 20 to 40 inches by quartz diorite parent rock.

This soil is used for pasture, tobacco, sugarcane, and minor crops, ranking in acreage in the order named. It produces slightly better yields than the Cayaguá soils if it is well fertilized and properly managed. It would be greatly benefited by lime and manure.

Mabí clay.—Mabí clay is a productive soil occurring throughout the island on long low gentle slopes, in close association with the Múcara and related brown shallow soils of the uplands, within the humid section. This soil is derived from material that is in part residual and in part colluvial and alluvial. It is characterized by a grayish-brown neutral plastic heavy clay surface soil about 8 or 10 inches thick, which has good tilth when properly plowed and cultivated. The material in this layer is fairly high in organic matter and plant nutrients. The subsoil is yellowish-brown plastic sticky neutral heavy clay streaked with rust-brown and gray material. This layer gradually changes, at a depth ranging from 30 to 40 inches, to friable brown and yellowish-brown silty clay loam that crumbles readily between the fingers. The material grades into disintegrated tuffaceous rock material at a depth ranging from 4 to 12 feet. Small fine white specks of the rock material occur in all layers, indicating that bases probably are released continually as the specks disintegrate.

Areas of Mabí clay are smooth or slightly undulating with sufficient slope for adequate surface drainage. The subsoil, although plastic and sticky, is more pervious to both water and plant roots than the compact subsoils of the Sabana Seca, Candelero, and related soils.

This soil is moderately fertile, and it produces from 30 to 45 tons of gran cultura sugarcane season after season. It needs fertilizer every year when planted to either cane or tobacco, the two principal crops grown. Probably 85 percent of the land is planted to sugarcane, and 15 percent is in tobacco. Tobacco yields range from 900 to 1,200 pounds to the acre when the land is well managed.

Mabí clay, flat phase.—Mabí clay, flat phase, is an extensive soil occurring throughout the humid part of the island, in close association with the typical soil.

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As far as could be detected in the field, this soil and the typical soil are identical in physical and chemical characteristics, but, owing to its nearly flat relief, the land use of the flatter soil differs considerably from that of the typical soil. Exclusive of artificial drainage, nearly all of this flat soil is drained externally, and, during the rainy season, water stands on the surface for several days at a time, owing to the very slow downward movement of moisture. In many places young cane is either killed or greatly weakened by the stagnant water. Adequate artificial drainage is difficult to maintain. Even with fairly numerous ditches water drains slowly, and cultivation often is long delayed. Open ditches are the most successful method of drainage, as tile drains soon become ineffective.

Nearly all of this soil is planted to sugarcane or is in a rest stage and will soon be planted. With careful management this soil is as productive as the typical soil.

FIGURE 118.—Sugarcane on the slightly rolling hills of Moca clay and Lares clay at Central Plata. The high hills in the distance consist mostly of Cialitos clay. The mean annual rainfall in this area is about 100 inches.

Caña en las colinas ligeramente ondulantes del Moca arcilloso y Lares arcilloso en la Central Plata. Los montes altos a lo lejos consisten principalmente de Cialitos arcilloso. La lluvia anual en esta área es de 100 pulgadas.

Moca clay.—Moca clay occurs to the south of the limestone escarpment extending from Moca to Toa Alta and in deep limestone valleys lower than the Tertiary limestone. It is derived from lower Tertiary clays. The 6- or 8-inch surface soil ranges from dark-brown to reddish-brown medium-friable semigranular plastic acid heavy clay, very sticky when wet but having very good tilth when moist. The subsoil is mottled dark-gray, red, and brown acid very plastic sticky clay that is generally wet, even during extended dry periods. This layer extends downward to a depth below 5 feet, where it grades

into mottled gray and red plastic acid clay interbedded with rounded rocks and gravel.

Areas of this soil are undulating or slightly rolling. Drainage is fair, and when fertilized the land produces from 35 to 45 tons an acre of gran cultura cane. Considerable areas in the vicinity of Moca are planted to this crop (fig. 118). Ñames yield from 5,000 to 8,000 pounds to the acre.

Gully erosion is very serious on this soil, probably more so than on any other. In places eroded spots show up from a distance as gullies. Sugarcane is usually planted in banks. In most fields the drainage furrows are numerous, and many of them extend at right angles to each other; but even under such conditions, if the slope is more than 15 percent, the furrows will erode.

Moca silty clay loam.—Moca silty clay loam is developed mainly between Bayamón and Corozal, although many small areas lie farther west. This soil differs from Moca clay in that it has less clay in all layers. It is used for the production of sugarcane, pineapples, grapefruit, and minor crops, especially ñames, all of which yield moderately well when the land is fertilized. Yields on unfertilized areas are very low.

Gully erosion is severe on Moca silty clay loam, especially in places where the land is planted to pineapples and clean-cultivated minor truck crops. The soil responds favorably to high applications of lime, phosphorus, and manure.

A few areas of this soil occurring within the limestone section are covered with water during many months of the year, and such areas are shown on the soil map with swamp symbols. Most of these areas are small and produce only hydrophytic plants, such as cattails and reeds. It would be extremely difficult to drain most of the areas, therefore the land never has been cultivated.

Moca silty clay loam, steep phase.—Areas of Moca silty clay loam that have sufficient slope to affect the land use are mapped as a steep phase of the Moca soil. The soil in these areas is low in organic matter, as the surface run-off has washed away considerable quantities of surface soil, thereby exposing the less fertile plastic subsoil. On the concave slopes at the heads of drainageways, plant growth, especially of grapefruit trees, is considerably better than on the convex or ordinary slopes. Unless this steep soil is particularly well managed, erosion will reduce its productivity year after year. Even now large areas are adapted only for pasture.

Moca loam.—Moca loam is associated with Moca silty clay loam on low sloping areas near the limestone hills between Bayamón and Corozal. Moca loam is noticeably sandier in the surface soil than the other Moca soils, therefore it is better adapted for the production of grapefruit and truck crops. The land is easy to work, but as it is low in organic matter it requires large quantities of fertilizers.

This soil has an 8- or 10-inch brown or dark-brown friable loam or sandy loam acid surface soil, which abruptly changes to heavy plastic sticky acid silty clay or clay that is mottled red, gray, and brown. This layer continues downward for many feet. All layers contain a few rounded pieces of gravel or small rocks.

Dominguito clay.—Dominguito clay is easily recognized by its nearly black clay surface soil and mottled sticky subsoil. It occupies

nearly level or slightly rolling areas associated with Moca clay, from which soil it differs in that it has a darker surface soil.

The topmost 6 or 8 inches of Dominguito clay is dark grayish-brown or nearly black plastic clay containing considerable organic matter. Unless this soil is plowed at the right moisture content, large dense clods are formed, which require several harrowings to break down to a good tilth. In most areas the subsoil is mottled gray, yellow, and red plastic sticky wet clay, which continues downward to a depth of more than 8 feet. The upper part of the subsoil generally is less mottled with red and gray than the lower part. The soil materials in all layers are very acid and in most places have a reaction of pH 5.0 or less. More than 90 percent of this land is used for sugarcane. P. O. J. 2878 grows very well and yields from 40 to 45 tons an acre of gran cultura. This soil requires careful management, as underdrainage is not very good, and in level areas drainage ditches are essential. Sugarcane is usually planted according to the grand-bank system, even on the more rolling areas. Tobacco yields range from fair to good, especially on the areas near Esperanza.

Gully erosion is severe on sloping areas. In the vicinity of Central Soller, many small limestone outcrops occur in the larger areas of this soil.

Río Arriba clay.—Río Arriba clay occurs only in the northeastern part of the island, mainly between Mameyes and Ceiba and between Ceiba and Naguabo. It is not an extensive soil. It is similar to Moca clay in many characteristics, as it occupies similar relief, is very acid, has a mottled red and gray plastic sticky subsoil, and has scattered through the profile many water-worn rocks that are nearly identical with those in the Moca and Dominguito soils.

Río Arriba clay has a much lighter colored surface soil than Moca clay. It is characterized by a light-gray or light yellowish-brown strongly acid medium friable clay surface soil about 6 inches thick that is very plastic and is darker when wet. Clods from any layer of this soil are hard and dense when dry, and they do not slake nearly so readily as do those in the Coto, Catalina, or Coloso soils. The subsoil is mottled red and yellowish-brown plastic sticky acid clay, which continues downward to a depth of more than 4 feet. The lower part of this layer has more gray and red mottlings and less brown than the upper part. Below a depth of 4 feet the soil becomes more friable and less heavy and is of a mottled gray and yellowish-red color. It is interbedded with rock fragments, some of which are 2 or 3 inches in diameter.

This soil occupies narrow gently sloping areas near streams, and it is used for the production of sugarcane if it is within economical hauling distance from a sugar central. The other areas are planted to minor crops or are in pasture grasses. Río Arriba clay is about as productive as Moca clay, and it needs lime and fertilizers for profitable production of crops.

Santa Clara clay.—Santa Clara clay is a fertile dark-colored soil occurring throughout all the humid sections of the soft limestone belts. It occupies low undulating hills and gentle slopes near drainageways. It has a 6-inch grayish-brown or dark grayish-brown neutral distinctly granular plastic clay surface soil. It generally plows up in large dense clods which require many dashing showers to slake to their natural good granular condition. The subsoil consists

of yellowish-brown alkaline plastic heavy clay, which gradually changes, at a depth ranging from 12 to 20 inches, to grayish-yellow more friable calcareous clay or clay loam. At an average depth of 2 feet, soft parent limestone is reached. In cultivated fields, variations in color give the surface soil a mottled or spotted appearance of black and grayish brown. Where possible the black areas are mapped separately and designated Camagüey silty clay. Santa Clara clay is very productive and almost all of the land is tillable. Most of it it planted to sugarcane, which yields from 35 to 45 tons of gran cultura an acre (fig. 119). Because of its sloping relief, this soil has good drainage. It requires careful management for best results, as it is very sticky and plastic and can be greatly harmed if plowed when either too wet or too dry. Areas near the coast are somewhat more granular than those inland and are less hard to till; they are used mostly for sugarcane and tobacco.

FIGURE 119.—Gathering sugarcane on Santa Clara clay. Gran cultura crops yield from 35 to 45 tons an acre. This soil has excellent tilth, but on steep slopes it erodes when improperly cultivated. Owing to the dense growth of cane, this is one of the best cultivated crops that can be planted for the prevention of serious sheet erosion.

Recogiendo caña en Santa Clara arcilloso. La gran cultura produce de 35 a 45 toneladas. Este suelo tiene excelentes condiciones para el cultivo, pero en declives escarpados se desgasta rápidamente cuando es mal cultivado. Debido al crecimiento espeso, la caña es uno de los cultivos mejores para prevenir erosión superficial.

Santa Clara clay loam.—Santa Clara clay loam differs from Santa Clara clay in that it is slightly less heavy and contains less clay in all layers. Both soils are used for the production of the same crops, and both produce about the same yields.

Camagüey silty clay.—Camagüey silty clay is easily recognized by its nearly black granular surface soil and yellow plastic sticky subsoil overlying soft limestone rock. This soil is widely distributed throughout the limestone hills of the humid section, from Central Canóvanas to Central Coloso. It occurs on nearly level or gentle slopes that

extend from the soft limestone hills to the flood plains or to the terraces and alluvial fans.

Camagüey silty clay is a highly productive soil occurring in Cuba, Puerto Rico, and probably in Haiti. It is somewhat similar to the Houston soils of southern United States. The surface soil, to a depth ranging from 6 to 16 inches, when wet is very dark grayish-brown or nearly black plastic waxy but granular silty clay or clay that cracks readily on drying and becomes slightly lighter in color. Numerous cracks 1 or 2 inches wide can be observed on dry areas which have not been disturbed recently. Just beneath the surface layer is yellowish-brown or yellow clay, which is plastic and sticky when wet and hart and dense when dry. Below this layer is the lime zone, which in mosd places occurs at a depth ranging from 18 to 30 inches, depending on the slope. The steeper the slope the nearer the lime is to the surface. The material in this layer is lighter in texture and color and more friable than that in the layer above. The lime occurs in rounded concretions and in disseminated form. At a depth ranging from 3 to 4 feet, this layer grades into friable olive or mottled light yellowish-brown, dark-gray, and rusty-brown calcareous silty clay loam. Limestone rock lies at a depth ranging from 40 to 70 inches.

Most of this land is planted to sugarcane, which yields from 40 to 45 tons to the acre gran cultura under good management without irrigation but with an acre application of about 500 pounds of fertilizer.

This soil is difficult to plow or to cultivate, owing to the heavy tenacious clay surface soil and the plastic sticky subsoil. It must be plowed when it is neither too wet nor too dry, and the plow should not mix very much of the yellow subsoil with the black surface soil. Drainage ditches must be so constructed as to drain the surplus water but not cause any serious gully erosion. P. O. J. 2878 is the principal variety of sugarcane grown on this soil. Much of the cane is planted in holes or shallow banks, but some is planted in furrows. Although this soil is high in organic matter, in order to maintain its fertility it requires an acre application of about 300 pounds of 12–6–5 fertilizer and 300 pounds of ammonium sulfate, when it is planted to sugarcane.

This soil is so intimately associated with the Santa Clara and Colinas soils that many very small areas of the latter two soils are included within areas shown on the map as Camagüey silty clay, and vice versa.

This soil would be productive for corn, beans, bananas, tobacco, coffee, and other crops, but as sugarcane is more profitable nearly the entire area is used for this crop. The soil is too alkaline for the profitable production of pineapples and has too heavy a subsoil for grapefruit trees.

Camagüey clay loam.—Camagüey clay loam also is a productive soil occurring in close association with Camagüey silty clay in the humid sections. This soil differs from Camagüey silty clay in that it contains less clay in the surface soil, which is also thinner, owing in part to its slightly more sloping relief.

This soil is slightly less productive than Camagüey silty clay, but it requires just as careful management. Nearly all of it is used for the production of sugarcane if the land is accessible; otherwise it is

planted to tobacco, minor crops, and coffee. Neither pineapples nor grapefruit grow well on it.

Yauco clay.—Yauco clay is the soil developed on the gentle slopes of the soft limestone hills and on the low rolling limestone hills in the arid districts between Aguirre and Boquerón. It is a dark-colored soil, very similar in appearance to Ponceña clay. Yauco clay is a productive soil when irrigated, but owing to its unfavorable relief irrigation is economical in only a few places. One area about 1½ miles southwest of Central Aguirre is irrigated and planted to sugarcane, which yields fairly well. When this area first was irrigated seepage from the unlined canals caused salt-water springs to form in some of the lower lying parts, thereby injuring both the soil and the crops. These areas can be drained easily, or seepage can be controlled by lining the canals. Lime chlorosis is especially injurious to sugarcane on some of the most shallow areas of this soil, and it reduces the yield of ratoon crops to a marked extent.

The 8- or 10-inch surface soil is cohesive calcareous granular friable dark grayish-brown clay that is plastic and sticky when wet. The subsoil is yellowish-brown semigranular friable calcareous clay that also is plastic and sticky when wet. This layer grades into soft white limestone rock at a depth ranging from 14 inches on the upper slopes and ridge tops to 30 inches on the lower slopes and level areas. Lime chlorosis is most noticeable in places where limestone is within 14 inches of the surface and may be exposed during deep plowing.

Unirrigated areas of this soil are used for pasture and corn, both of which grow about as well as on Pozo Blanco clay loam. The crops produced are much superior in quality to those grown on some of the red acid highly leached soils of the humid sections. A few of the better areas will produce from 20 to 22 tons of the Uba variety of sugarcane to the acre during favorable years, without irrigation.

Within areas of this soil are many areas of Ponceña clay that are too small to be mapped separately.

Yauco clay, colluvial phase.—A colluvial phase of Yauco clay occurs at the bases of some limestone hills. This soil differs from the typical soil in that it contains considerable limestone rock fragments from the surface to the underlying calcareous rock.

The surface soil of Yauco clay, colluvial phase, to a depth of 6 or 9 inches, is light grayish-brown granular very calcareous clay with numerous small limestone rocks strewn over the surface. The subsoil, to a depth ranging from 24 to 30 inches, is light-brown or grayish-brown calcareous medium friable silty clay containing many limestone fragments. This layer is underlain by partly disintegrated limestone fragments and limestone gravel, which grade into soft limestone rock.

Most areas of this soil are used for range pasture, but a few are irrigated and used for sugarcane, which produces from 30 to 35 tons of gran cultura to the acre. In areas where the limestone rocks are exposed, sugarcane is affected severely by lime chlorosis.

Ponceña clay.—Areas of Ponceña clay have a striking resemblance to areas of Camagüey silty clay. The separation of the two soils is based on the mean annual precipitation. Ponceña clay occurs in areas receiving about 45 inches and the Camagüey and Santa Clara soils receive from 65 to 100 inches.

This soil occurs on the smooth or slightly undulating inner plains of the south coast, in close association with the Aguilita soils (fig. 120). It is a very productive soil and is used extensively for the production of sugarcane. Irrigated areas yield from 45 to 60 tons to the acre of gran cultura, and unirrigated areas yield from 12 to 20 tons less.

Ponceña clay has a very dark grayish-brown or black distinctly granular plastic alkaline or neutral clay surface soil about 7 inches thick. This layer is underlain by a brown dense clay subsoil that averages about 24 inches in thickness. The material in this layer is very plastic and sticky when wet and breaks into hard, angular dense clods when dry. The subsoil is underlain by grayish-yellow medium-

FIGURE 120.—Oxen feeding on the cane leaves, or paja, after the sugarcane has been hauled to the mills. The undulating plains consist of Ponceña clay, and the brush- and grass-covered high hills are for the most part Aguilita and Descalabrado soils.

Bueyes comiendo hojas de caña o paja después que la caña ha sido llevada al molino. Los llanos ondulantes son Ponceña arcilloso, y los montes altos cubiertos de yerba y maleza son en su mayoría suelos Aguilita y Descalabrado.

friable faintly granular calcareous silty clay, which, in turn, is underlain by mottled olive and yellowish-brown friable calcareous silty clay or silty clay loam. The last two layers contain considerable free lime carbonate, which is in concretions and in disseminated form. Below a depth of 50 inches the content of visible lime decreases, but the soil effervesces freely with cold dilute hydrochloric acid. The parent material is composed of weathered calcareous shale and shaly limestone. This soil requires as careful management as either the Camagüey or Santa Clara soils. Sugarcane is usually planted in furrows. B. H. 10 (12) seems to be the principal variety grown at present.

Ponceña clay, eroded phase.—Areas of Ponceña clay occurring along the drainage slopes have a thin surface soil and are classified as an eroded phase of the typical soil. Many such areas have a slope ranging from 30 to 40 percent, and both the surface soil and subsoil have been washed away, exposing the gray limy substratum.

This soil is not extensive, and most of it is planted to sugarcane in connection with the adjacent areas of the typical soil. Some areas that have a thicker surface layer are in pasture grass. This soil is less than one-fifth as valuable as the typical soil.

Portugués clay.—Portugués clay is so closely associated with and so similar to Ponceña clay that the boundaries between the two soils are drawn arbitrarily. Soft friable limestone rock occurs at less depth under the Portugués soil than under the Ponceña soils.

The surface soil of Portugués clay is very dark grayish-brown or black distinctly granular friable calcareous clay about 8 inches thick. This layer is very plastic and waxy when wet and is then difficult to plow. The subsoil, to a depth of 18 or 20 inches, is yellowish-brown medium-compact cloddy calcareous clay which gradually changes to more friable light yellowish-brown silty clay loam containing many lime concretions and lime splotches. This layer is underlain by soft friable limestone at a depth of about 3 feet.

The relief is undulating or gently sloping. The soil occurs only in the vicinities of Ponce and Juana Díaz. If irrigated, it is used exclusively for the production of sugarcane, which yields about the same as on Ponceña clay. Owing to the high lime content of the soil, some of the sugarcane is affected with chlorosis, which reduces the yield from 50 to 100 percent in the patches affected. Nonirrigated areas are used for tobacco and pasture. The pasture is of excellent quality, and tobacco yields about 800 pounds to the acre during favorable years.

Mercedita clay.—Mercedita clay resembles Portugués clay as closely as Portugués clay resembles Ponceña clay. These three soils and Yauco clay are very closely related and are similar in many respects.

Mercedita clay differs from Portugués clay in that it has a browner surface soil and many areas are strongly impregnated with alkali. The Mercedita soil has been influenced by wash from the nearby limestone hills to much greater extent than either the Ponceña or Portugués soils.

The 12-inch surface soil of Mercedita clay consists of brown or dark grayish-brown granular calcareous clay, which is very plastic and waxy when wet. The subsoil is yellowish-brown or light olive-brown medium-compact plastic calcareous clay ranging from 10 to 15 inches in thickness. Below this layer is very limy friable light-yellow silty material and soft limestone, which continues below a depth of 5 feet.

Probably 20 percent of the area of Mercedita clay contains harmful quantities of sodium carbonate, and these areas are wasteland or are used for overnight pasture for the oxen. The remaining 80 percent is used for the production of sugarcane, which yields from 30 to 60 tons of gran cultura. Many areas of this soil are affected with lime chlorosis (fig. 28), which greatly reduces the yields. Manure and sulfur should help the areas affected with chlorosis and alkali.

This soil is not extensive. Most of it is included in the few fair-sized areas near Central Mercedita, which is east of Ponce, and the few small areas near Hacienda Matilde, which is southwest of Ponce.

Barrancas clay.—Barrancas clay occupies a few long narrow strips adjacent to stream courses between Ponce and Guayama. This soil occurs in low imperfectly drained positions, especially between areas of the Ponceña and the Portugués soils. To a depth of 2 feet or more it consists of nearly black plastic clay underlain by dark-gray clay.

At a depth of 40 or more inches the color is light gray mottled with small specks of lime and yellowish-brown iron stains.

This soil is poorly drained and in many places contains some harmful soluble salts. Some of the salt-free areas are irrigated and planted to sugarcane, which yields from 30 to 40 tons if the land is fertilized and properly managed. Many areas of this soil are in pasture, owing to the great expense involved in draining and irrigating it.

A few areas are affected with small springs and are wet most of the year. These areas are not used to a great extent for cultivated crops.

Barrancas silty clay loam.—The surface soil of Barrancas silty clay loam is very dark grayish-brown granular alkaline silty clay loam about 14 inches thick. The subsoil consists of dark-gray plastic calcareous clay about 20 inches thick, which is underlain by a mottled dark-gray and light-brown gravelly loam upper substratum. Below a depth of about 4 feet, the material is light-brown sandy loam mottled with gray, blue, yellow, and red.

This soil occupies a very few small areas on high alluvial fans, chiefly on Hacienda Ponceña. It is a fairly good soil for sugarcane.

Pozo Blanco clay.—Pozo Blanco clay is a reddish-brown soil occupying very small areas in the nearly level small valleys in the arid section between Ponce and Parguera. Most of this land lies fairly near the coast. The soil is derived from limestone materials that have been washed from the adjacent hills.

The 8-inch surface soil of Pozo Blanco clay is friable calcareous distinctly granular dark reddish-brown clay. It is underlain by reddish-brown calcareous medium-friable clay that is plastic when wet but not nearly so plastic as most of the other soils of the inner plains. The material in this layer gradually becomes more friable and less heavy with depth. It contains limestone fragments at a depth of about 14 inches, and soft limestone is present at a depth of about 2 feet.

This soil occurs in districts that do not have irrigation, therefore nearly all of the land is used for pasture and the production of corn and subsistence crops. Yields are fairly good during favorable years, but in many years crops die from lack of moisture.

Comparatively speaking, this soil is neither very extensive nor important. It would be more important if it could be irrigated economically.

Pozo Blanco clay loam.—Pozo Blanco clay loam is very similar to Pozo Blanco clay, and it occurs in the same general localities. It occupies smooth nearly level well-drained areas in the arid sections. It is more friable and less difficult to plow or cultivate than is Pozo Blanco clay, and it is also more productive.

The 5-inch surface layer of Pozo Blanco clay loam consists of dark reddish-brown friable granular calcareous clay loam, which grades downward into lighter red friable clay loam that contains much free lime and some limestone fragments. Below a depth ranging from 20 to 26 inches is soft friable white limestone rock. This soil is friable and is easily penetrated by moisture and plant roots. Nearly all of the land is used for corn, pasture, and subsistence crops, ranking in acreage in the order named. Corn yields from 15 to 20 bushels to the acre, depending on the rainfall during the growing season. Subsistence crops produce very well during favorable years. If this soil were irrigated, it would be productive for sugarcane.

Amelia clay.—Amelia clay is the brown somewhat shallow soil that occupies the long gentle slopes and valleylike positions between many of the hills in the arid and semiarid sections. In general this soil is associated with the Descalabrado and Aguilita soils, but in the southwestern part of the island it is associated with the Jácana and Guayama soils. Areas of the Amelia soil occur between Guayama and Boquerón.

The 5- to 7-inch surface soil ranges from brown to nearly black granular friable alkaline clay. The color depends on the average annual rainfall; the greater the rainfall the darker the soil. The subsoil gradually changes from brown medium-compact alkaline heavy clay to yellowish-brown more friable clay containing many nearly cubical rock fragments. At a depth ranging from 24 to 30 inches is a yellowish-brown alkaline porous rock, the upper part of which is partly disintegrated. This soil is intermediate between the deep Coamo soils and the fairly shallow Descalabrado silty clay, rolling phase, and therefore has some characteristics of the soils of both series. The areas nearer the Coamo soils are more similar to those soils, and the areas near the Descalabrado soils are more similar to the latter soils. Some areas of the Amelia soil have decidedly reddish brown subsoils.

Most areas of Amelia clay are used as range land for cattle. The cattle grow exceedingly well during the rainy season, but starvation among them is not uncommon during the dry season. The carrying capacity of this land is about twice as great as that of land on the adjacent hills. Some areas are planted to tobacco, which produces about 800 pounds to the acre in favorable years. Sugarcane is planted if the land is irrigated, and it produces from 30 to 35 tons to the acre when fertilized.

Río Cañas clay.—Río Cañas clay is very closely related to Amelia clay. It differs from that soil in that it contains free lime between depths of 15 and 30 inches. The upper 6- to 8-inch layer of Río Cañas clay is brown granular neutral clay, which is underlain by yellowish-brown medium-compact alkaline heavy clay that continues to a depth of about 15 inches. The substratum is light yellowish-brown calcareous friable silty clay loam containing many specks, splotches, and concretions of lime. Tuffaceous rock occurs at a depth of about 30 inches. The upper part of the rock can be penetrated easily by plant roots. All layers of this soil contain various-sized rectangular-shaped rock fragments.

Nearly all of this soil occurs east of Juana Díaz, Arriba, and Río Cañas Abajo, near Río Cañas and northwest of Salinas. The land is used for pasture and the production of tobacco. It is as productive as Amelia clay, and the two soils should be managed in the same way.

Cabo Rojo clay.—Cabo Rojo clay is similar to Río Arriba clay, but it occurs in arid and semiarid sections and is considered a very poor agricultural soil. This soil occurs in undulating or rolling areas only in the vicinity of Faro Cabo Rojo, near Boquerón, and southwest of Cabo Rojo. It is fairly extensive within these three areas.

Cabo Rojo clay has a light grayish-brown or yellowish-brown strongly acid plastic clay surface soil about 6 inches thick that is leached and has poor structure. The upper part of the subsoil is yellowish-brown sticky plastic acid clay which gradually changes to the lower part—mottled gray, red, and reddish-brown very plastic

sticky acid clay. This layer is underlain, at a depth of about 3 feet, by more friable less sticky mottled gray or greenish-gray and brown acid clay. All layers contain conspicuous but small rock fragments and rounded pieces of gravel, consisting chiefly of flint, quartz, and other siliceous rocks.

Areas of this soil are rather easily identified by the poor condition of the crops growing on them or the eroded and neglected appearance of the land. This land produces fairly thick stands of grass, but when it is cultivated to crops, of which the Uba variety of sugarcane is dominant, yields are so low after the second or third year that many bare spots occur in the field, and soon the effects of erosion are very conspicuous. The surface soil becomes very thin, and gullies ranging from 2 to 4 feet in depth extend an eighth of a mile across the fields. The fertility of the land becomes so low that grass is slow in becoming reestablished, and erosion keeps the soil exposed. Sugarcane grows so slowly that large fields of it cannot survive the attacks of aphids.

Probably 50 percent of this soil is idle or has grown up to nearly valueless brush, weeds, and grass. This is especially true of all areas that have been cultivated. Areas that have been in pasture for a long time still produce fair grass, although not nearly so good as that on the associated alkaline soils, such as the Fraternidad and Paso Seco.

Areas shown on the soil map with stone symbols are slightly less heavy in the surface soil, and they contain an abundance of gravel and rounded rocks from the surface to a great depth. Most of these areas are correctly used as pastures. Some are very closely associated with Guayama clay and have a distinct red tinge in the surface soil. Guinea grass should be planted in individual holes without disturbing the surrounding soil.

Cabo Rojo clay, rolling phase.—Areas of Cabo Rojo clay that occur on 15- to 30-percent slopes are classified as a rolling phase of that soil. These areas are even less desirable than the typical soil, as erosion is more severe and harder to control after it once starts. Gullies are conspicuous in all the cultivated areas.

This soil differs little from the typical soil, except in relief. Most areas are now used as pasture land, although many were cultivated at one time and later abandoned.

SOILS OF THE TERRACES AND ALLUVIAL FANS

The soils of the terraces and alluvial fans include soils derived from material washed from the uplands and deposited along and near streams, but they now occupy elevations above overflow and do not receive additional material by deposition. In general the terraces occupy positions adjacent to streams but many feet above normal flow, owing to entrenchment of the stream channels since the alluvial material was first deposited. The deepening or entrenchment of the streams has been caused in part by the uplift of the island in fairly recent geologic times. Most of such soils are much older than soils of the river flood plains and are more fully developed.

The soils of the alluvial fans have been formed by material flushed into the valley from the mouths of streams in the arid and semiarid sections. Within this area many intermittent streams originate in the volcanic hills and terminate in the valleys or coastal plains, forming alluvial fans that coalesce and extend to and in many places over-

lap the soils of the coastal lowlands. The age of the alluvial fans ranges from fairly recent to very old. In both the terraces and alluvial fans the soil materials have been unmolested a sufficient length of time for soil-forming processes to have their effect on the soil layers.

Most of the soils of the terraces and alluvial fans slope gently toward the sea or toward streams, therefore they have fairly good natural surface drainage. Most of these soils are heavy in texture, have a high water-holding capacity, are deep, occupy fairly large uniform areas, and are very productive. They are well adapted for the production of sugarcane, which occupies from 80 to 85 percent of their total area.

The soils of the terraces and alluvial fans are divided into two divisions, namely, (1) medium-friable soils and (2) compact soils.

MEDIUM-FRIABLE SOILS OF THE TERRACES AND ALLUVIAL FANS

The medium-friable soils of the terraces and alluvial fans include 40 soil types and phases of the Torres, Vía, Lares, Fajardo, Humacao, and Mayo series, of the humid sections, and the Resolución, Llave, Arcadia, Coamo, Machete, and Vives series of the arid and semiarid sections.

Typically, the Torres soils occupy well-defined terraces that have been formed by materials washed from the Catalina, Cialitos, and other red and purple acid soils of the uplands. In many places they exceed 1,000 feet in elevation. They have brown or reddish-brown fairly thick friable acid surface soils underlain by permeable medium-compact heavy-textured red or brownish-red very acid subsoils. The substratum is friable light-red acid loamy material that is stratified with layers of water-worn rocks and gravel.

These soils have been leached to a considerable extent and are fairly low in bases and organic matter. They have, however, favorable relief for general farming and are adequately drained, both externally and internally. Generally speaking, the Torres soils are well adapted for the production of almost all crops commonly grown in Puerto Rico, and fair to good yields are obtained if commercial fertilizers are used. Legumes, lime, and manure would help to increase the yield of crops and to maintain the fertility of the land.

Erosion is a factor that must be considered in the cultivation of all slopes exceeding 15 percent. Some areas that have been seriously injured by both sheet and gully erosion are used only for pasture.

The Vía soils occur on undulating terraces and on alluvial fans along the sides of river valleys at elevations of less than 250 feet, where torrential streams have carried considerable mixed debris and gravel from the tuffaceous hills and deposited them on the long slopes adjacent to stream courses. The materials have been deposited a sufficient length of time to allow the soil-forming processes to develop a rather definite soil profile, and many of the rocks have weathered to fine soil particles. The soil texture and thickness of the various layers differ greatly, according to the locality.

The Vía soil areas on the map include many small local poorly drained spots that need artificial drainage. They also include many small gravelly spots that are droughty and unproductive.

As these soils have been derived mostly from the material washed from the Múcara and associated neutral young soils, they have a

higher content of bases and plant nutrients than the Torres and Lares soils that have been washed from older more leached soils. The Vía soils have been leached to some extent by meteoric water, which has reduced the natural fertility of the soil. It is necessary to use commercial fertilizers besides making occasional applications of lime. The planting and plowing under of legumes would also be very beneficial for these soils.

The Lares soils are very similar in position and physical characteristics to the Torres soils, but as they are derived from material washed from the lower Tertiary clays and shales, they generally lie to the south of and parallel with the limestone escarpment that extends from Moca nearly to Bayamón. They range in elevation from 30 to more than 1,000 feet. The Lares soils are well developed, and at one time they had nearly level relief, but now, owing to the numerous natural drainage courses, many areas have sloping or steep relief. The more level areas are well adapted to the production of almost any crop grown on the island. Grapefruit, sugarcane, coffee, pineapples, and minor crops occupy from 85 to 90 percent of the total area. The acreage of these crops is about equally divided. Most of the steep areas are in pasture or coffee.

The Fajardo soils are closely associated with the Río Piedras soils and are derived from material washed from those soils and the Yunes soils. They are in part residual, in part colluvial, and in part composed of old alluvium. Most areas lie at an elevation of less than 500 feet. The relief is gently sloping from the adjacent hills to the stream channels, and the areas in general are long and narrow. Most of the areas are near sugar centrals and are used almost entirely for the production of sugarcane, which yields about 35 tons to the acre year after year when the land is properly fertilized.

The surface soils are brown, heavy, acid, and plastic when wet. The subsoils are moderately compact reddish-brown acid clay with a cubical structure. The substratum is mottled red, yellowish-brown, and brown cubical clay that extends downward to a depth of many feet.

The Humacao, Mayo, Resolución, Llave, and Arcadia soils are derived, all or in part, from similar granitic materials, and they occur at elevations ranging from 10 to 150 feet above sea level. The Humacao and Mayo soils are developed in the east-central part where the mean annual rainfall is between 70 and 80 inches. The Resolución, Llave, and Arcadia soils occur only in Isla de Vieques, where the mean annual rainfall is about 40 inches. The Humacao and Mayo soils are lighter colored, more leached, and much more acid than the soils derived from granitic materials in Isla de Vieques. The Humacao soils have much heavier subsoils than the Mayo soils and are better adapted to sugarcane, the crop that occupies nearly 100 percent of their total area. The soils of both series are light in color and have gritty friable sandy substrata. They are well drained. The Humacao soils occupy more definite terrace positions, and the Mayo soils occupy the alluvial fans. The principal variety of sugarcane produced on these soils is B. H. 10 (12) which is planted in furrows and fertilized heavily with commercial fertilizers high in nitrogen. These soils are not irrigated.

The Resolución soils are darker, deeper, and more productive than either the Llave or the Arcadia soils. The Llave soils occupy definite terrace positions and are derived entirely from granitic materials;

both the Resolución and Arcadia soils have been influenced to some extent by tuffaceous materials. These soils occupy a small total area, but they are productive for sugarcane and corn. Water is not available for irrigation on Isla de Vieques, and the soils are neither irrigated nor fertilized. It does not seem to pay to fertilize land in arid sections, as sugarcane develops a vigorous top growth, but the roots do not penetrate deeply for water, therefore during the dry season the crop suffers seriously from lack of moisture. Sugarcane is always planted in deep furrows, and the cane cuttings or seeds are planted farther apart than in the humid or irrigated sections. A yield of 20 or 25 tons of sugarcane is considered good for these soils. The common practice is to have many ratoon crops and plant the S. C. 12/4 and Uba varieties, although Mayagüez 28 has produced fair yields on some of these soils.

The Coamo soils occupy distinct terrace positions within the semiarid sections, at elevations ranging from 300 to 500 feet. They are derived from material washed from the alkaline brown shallow Descalabrado soils. The Coamo soils are dark-colored calcareous heavy-textured soils high in organic matter and bases. Owing to their position, a very small proportion of their area can be irrigated, and pasture grass occupies about 80 percent of these soils. Sugarcane would be very productive if sufficient water were available.

The Machete and Vives soils occupy terrace and alluvial-fan positions in semiarid sections, at elevations of less than 250 feet. They are derived from material washed from the reddish-brown alkaline Guayama soils. The Machete soils differ from the Vives in that they have reddish-brown surface soils, whereas the surface soils of the Vives soils are dark grayish brown. In other respects soils of the two series are very similar. The subsoils are medium-friable, heavy, alkaline or neutral, and red or reddish brown. The substratum is lighter in texture, more friable, and less red than the surface soil. Nearly the entire area of these soils is irrigated and planted to sugarcane, which has an acre production ranging from 55 to 70 tons gran cultura, from 40 to 50 tons of primavera, and from 30 to 35 tons in ratoon crops. B. H. 10 (12), the principal variety grown, is planted in furrows, fertilized with from 300 to 400 pounds of 12–8–4 at the first application and 300 pounds of ammonium sulfate as a second application, and irrigated from 12 to 20 times, depending on the season and the length of the growing period.

Torres clay.—Torres clay is a well-developed soil that occurs on the undulating or level terraces adjacent to some of the mountain streams. It is derived from material washed from the Catalina, Cialitos, and associated red and purple soils of the uplands in the humid sections. It is, as might be expected, red, acid, deep, permeable, and fairly fertile.

The 6- or 8-inch surface soil of Torres clay is yellowish-brown or brown, fairly mellow, slightly granular acid clay, underlain by a red or brownish-red moderately compact acid silty clay subsoil about 20 inches thick. The lower part of the subsoil is streaked with gray and yellow materials. The substratum consists of friable reddish-brown or red gravelly loam or clay loam that extends downward to a depth of more than 6 feet.

This soil has the necessary requirements for a productive soil, such as a friable surface soil, fairly high in organic matter; a thick, medium-

permeable subsoil; a deep friable substratum; and no serious amounts of gravel or harmful salts in any of the layers. The soil, however, is strongly acid and needs both lime and fertilizer for the best production of tobacco, sugarcane, and some of the minor crops. Coffee grows very well without soil amendments, but higher yields would be obtained with the addition of fertilizers high in potash and nitrogen.

Most areas of this soil occurring in the vicinity of Lares, Mayagüez, and other coffee districts are used for the production of coffee. Areas near La Muda are used for the growing of sugarcane and minor crops. Almost all of the land is cultivated. Sheet erosion is rather serious in areas that have a slope exceeding 15 percent and that are improperly cultivated.

Torres clay, steep phase.—Areas of Torres clay that occupy slopes adjacent to streams and gullies caused by erosion are classified as Torres clay, steep phase. This soil differs from the typical soil in that it has a much shallower surface soil, owing to the steep relief and greater amount of sheet and gully erosion. Nearly all of the land is used for pasture, which has about the same carrying capacity as the pasture on Fajardo clay, steep phase.

Torres silty clay loam.—Torres silty clay loam is the most widely distributed soil of the Torres series. It is a well-drained well-developed soil occupying small areas on many of the terraces along the streams near Fajardo, Moca, Luquillo, Torres, and Santa María. It differs little from Torres clay other than in having a slightly lighter textured and more easily worked surface soil.

Most areas of this soil are sufficiently large to be cultivated by modern machinery. The largest proportion of the land is planted to sugarcane, which yields from 30 to 40 tons in gran cultura plantings. B. H. 10 (12) and P. O. J. 2878 are well-adapted varieties. For the most successful management of this soil, lime and fertilizer are necessary.

Vía silty clay.—Vía silty clay is a light-colored well-drained soil occurring on low nearly level terraces associated with the Estación soils of the river flood plains. The Vía soil is fairly extensive and occurs in areas large enough to be worked with modern machinery. Nearly all areas conveniently located to sugar centrals are used for the production of sugarcane, which, under favorable conditions, yields from 30 to 45 tons to the acre in gran cultura plantings. B. H. 10 (12) is the most common variety of sugarcane grown. The usual 300 pounds of 12–6–5 fertilizer is used as a first application, and 300 pounds of ammonium sulfate is used as a second application. Many areas along mountain streams far from a highway are used for the production of coffee or tobacco, and the yields obtained are much higher than those from the adjacent upland hills. One of the largest areas of this soil is in the Caguas lowlands, east of Gurabo. This area is used almost entirely for sugarcane.

This soil is characterized by a brown or light-brown friable semigranular acid silty clay surface soil about 10 inches thick, which is underlain by a brown or mottled light-brown and yellowish-brown acid medium-compact silty clay subsoil about 14 inches thick. The substratum consists of friable silt loam or loam, stratified in places with water-worn gravel and cobblestones.

This soil is well drained but not to the same extent as the Torres soils, as shown by the mottled color of the subsoil—an evidence of restricted drainage.

Farmers consider this soil very productive, and it is valuable land for the production of sugarcane. It is never flooded, and drought does not affect it nearly so much as it does the sandier textured members of the Vía series or of the Estación series.

Vía silty clay, broken phase.—Vía silty clay, broken phase, consists of the steep short slopes between areas of typical Vía silty clay and the stream bottoms. This soil has a thin yellowish-brown acid silty clay or clay surface soil underlain by a brown acid medium-friable subsoil about 10 inches thick, which, in turn, is underlain by stratified sands and gravel.

This soil is used entirely as range pasture for goats, cattle, and horses. It produces fairly good grass and has a carrying capacity of one and one-half or two oxen an acre a year.

Vía clay loam.—Vía clay loam occurs in several widely scattered areas, such as those near Ciales, Peñuelas, and Playa de Humacao. This soil is similar in position, relief, and chemical characteristics to Vía silty clay, but it differs in physical characteristics in that it contains less silt and clay in all layers. The two soils are used for practically the same purposes, and the yields obtained are about the same on both.

Both soils need fertilizers and some lime for best crop yields. These soils occur in places where the rainfall is sufficient for most crops, but additional water by irrigation would increase the crop yields. Most areas, however, are so situated that they are exceedingly difficult to irrigate.

Vía silt loam.—Vía silt loam is confined to the undulating or nearly level terraces and alluvial fans in the east-central part of the island, between Caguas and Naguabo.

This soil is more friable and contains less clay than Vía clay loam, but in most other respects the two soils are nearly identical.

Vía silt loam is not extensive. Most of the land is planted to sugarcane, and yields are about the same as those obtained on Vía silty clay or Vía clay loam. Some areas of this soil have considerable gravel in all layers and even on the surface. Such spots have low productivity, but as they are so small they cannot be shown separately on the soil map.

Vía silt loam, broken phase.—Vía silt loam, broken phase, is very similar to Vía silty clay, broken phase, but it contains less silt and clay in all layers. It is used for pasture and minor crops. Whenever this soil is cultivated sheet erosion is severe and reduces the thickness of the surface soil to a marked extent. The land should be used only for pasture and forest.

Lares clay.—Lares clay occupies very old high well-drained terraces that have been eroded to such an extent that the relief ranges from strongly undulating to rolling. This soil has been derived from the wash from the Catalina and associated red acid soils and to less extent from the Múcara and associated brown soils.

Lares clay is a desirable soil for the production of coffee, sugarcane, pineapples, citrus, and minor crops, and the cultivated acreage is about equally divided among these crops.

The soil in an average field, recently cultivated, has the following characteristics: A light-brown slightly granular medium-friable acid clay surface soil about 7 inches thick, slightly plastic when wet and medium hard when dry; a mottled red, brown, and yellowish-brown medium-compact slightly plastic clay subsoil, which continues to a depth ranging from 24 to 30 inches; and a deep fairly friable distinctly mottled red, gray, and brown acid silty clay substratum resting on gravel at a depth of about 5 feet.

The water-holding capacity of this soil is sufficient to enable plants to withstand fairly long dry periods, yet neither the surface soil nor the subsoil is too compact to restrict rapid penetration of plant roots. This soil occurs in areas having a fairly high rainfall, and a considerable amount of the bases have been leached. Vegetation, however, grows quickly and densely, and therefore the content of organic matter is fairly high. As the soil is fairly permeable, deep, well drained, fairly rich in plant nutrients, and receives sufficient rainfall for most crops, it is used rather successfully for nearly every crop grown on the island. Areas penetrated by roads and within a few miles from sugar centrals are most profitably used for the production of sugarcane, yields of which range from 45 tons for gran cultura plantings to 25 tons for second ratoons. P. O. J. 2878 is one of the principal varieties of sugarcane grown, and it is usually planted in furrows. The most common fertilizer practice is to use 300 pounds of 12–6–5 fertilizer as a first application and 300 pounds of ammonium sulfate as a second application.

Average yields of other crops are as follows: Coffee, 200 pounds to the acre; grapefruit, from 5 to 15 boxes to the tree; pineapples, 250 crates to the acre; and ñames, 8,000 pounds to the acre.

The largest areas of Lares clay, which occur near Lares and San Sebastián, are used for the production of coffee and sugarcane; areas near Bayamón are used for grapefruit; areas near Morovis are used for pineapples; and in the vicinity of Moca, minor crops occupy large areas.

Lares clay, steep phase.—Throughout areas of Lares clay, especially near San Sebastián and Bayamón, some of the soil occupies strongly rolling or steep relief and is shown on the map as a steep phase of Lares clay. Most of these steep areas are near streams and along small natural drainageways. Nearly all of this soil near Bayamón is used for pasture and trees, and the areas near San Sebastián are planted to coffee. This soil is much less valuable than the typical soil, owing to the difference in relief. The soil characteristics are very similar to those of the typical soil, but the surface soil is more shallow and contains slightly less organic matter. If this soil were cultivated, gully erosion would be rather difficult to control.

Areas of this soil that are closely associated with the Múcara soils have darker brown subsoils than the typical areas, and areas closely associated with the Catalina soils have distinctly red subsoils similar to those of the Catalina soils.

Lares clay, red-subsoil phase.—Lares clay, red-subsoil phase, differs from Lares clay in that it has more perfect subsoil drainage, owing in part to the greater permeability of the material. For this reason the subsoil has better aeration and oxidation and therefore is more red than the subsoil of the typical soil.

This soil is not very extensive. It occurs in several widely separated areas on the high well-drained terrace along the north coast.

A plowed field has a dark-brown or yellowish-brown heavy slightly granular acid clay surface soil about 10 inches thick, which generally is very cloddy until it is well cultivated. Below this layer is the red acid clay subsoil, which is medium friable when dry and medium plastic when wet. The subsoil, which is about 12 inches thick, is well aerated and well drained, and these features account for the solid red color. Below a depth ranging from 20 to 24 inches is the mottled light-red, yellowish-brown, and gray medium-plastic light silty clay substratum, which becomes more mottled with depth, indicating less perfect drainage in the lower part. Some rounded gravel occurs in all layers, showing that at one time water had an influence on this soil.

Farmers prefer this soil to the typical soil for all agricultural crops, and a large proportion of it is used for the production of sugarcane.

Lares silty clay loam.—Lares silty clay loam occupies old terraces in a few places along the north coast, that have been formed chiefly by material washed from the Catalina soils and to less extent from the Múcara soils.

This soil has a 9-inch brown or brownish-gray granular acid silty clay loam surface soil, which is very plastic when wet. The subsoil, to a depth of about 28 inches, is dull yellowish-brown moderately friable acid clay mottled with red and rust-brown splotches and stained less conspicuously with gray and yellow. Below a depth of 30 inches, the mottling is less pronounced, and gray is the dominant color. Highly weathered gravel occurs at great depths.

This soil is used principally for the production of sugarcane, which yields from 40 to 50 tons to the acre in gran cultura plantings. The soil responds favorably to rather heavy applications of manure, fertilizers, and lime.

Lares clay loam.—Rather extensive areas of Lares clay loam occupy nearly level or undulating terracelike positions near Bayamón and in the vicinity of the presidio (insular penitentiary) near Río Piedras. In a cultivated field the heavy acid clay loam surface soil is brown or reddish-brown, and it crushes fairly easily into granules which contain some rounded quartz grains. At a depth of about 6 inches, the soil changes to red or brownish-red heavy medium-plastic clay that cracks to some extent on drying. In the lower part of this layer, generally at a depth of about 14 inches, is mottled red and yellowish-brown medium-friable clay. At a depth of about 40 inches, the material is friable red, yellow, and brown clay that continues to a great depth. In places it looks very much like mottled distintegrated tuff. A characteristic feature of this soil is the noticeable amount of water-rounded rocks on the surface and throughout the profile. Many of the rocks are flat and pitted. The rocks and gravel near the surface are coated with a layer about one-sixteenth of an inch thick, consisting of a dark ironlike cemented material, like that composing perdigón, although very few perdigones are noticeable except in places where this soil grades into the Sabana Seca soils. In many places, at the lower depths, there are gravel layers resembling water-deposited gravel. This rounded gravel is of shale, andesite, and tuff. This soil is acid in all layers.

FIGURE 121.—Undulating hills occupied mostly by Lares clay loam, which is used for the production of sugarcane, grapefruit, subsistence crops, and grass. Small patch of a Colinas soil in center, so alkaline that pineapples growing on it have become affected seriously by chlorosis.

Los montes ondulantes son principalmente del suelo Lares arcilloso lómico donde se cultiva caña, toronjas, frutos menores y yerba. Este pedazo de suelo Colinas es tán alcalino que las piñas han sido afectadas por clorosis.

This soil near the penitentiary is used mostly for the production of sugarcane and grapefruit (fig. 121). It is better adapted for sugarcane, as it is slightly too heavy for grapefruit. About the best variety of sugarcane now grown on this soil is P. O. J. 2878, acre yields of which range from about 30 to 45 tons of gran cultura. Areas of this soil west of Toa Baja are used for sugarcane and pasture. In this section there are a few sinks, which hold water for several months at a time. The rocks in this soil near Toa Baja may be more than a foot in diameter, but they do not seem to interfere with cultivation.

Lares sandy loam.—Lares sandy loam is closely associated with Lares clay loam near Bayamón. It differs from the clay loam in that is has a more friable sandier surface soil and a slightly less heavy more red subsoil. It is much better adapted to grapefruit and less well adapted to sugarcane than the clay loam. Areas of this soil near the Río Piedras-Guaynabo road are very valuable for the production of grapefruit, and some farms sell for $700 or $800 an acre. Areas of this soil near Cabo Rojo are more rolling than the areas near Río Piedras, and they have a slightly thicker sandier surface soil. The Uba variety of sugarcane, coconuts, and pasture grasses are the principal crops grown in this vicinity. Yields of sugarcane are very low compared with those on the nearby Coloso soils.

Fajardo clay.—Fajardo clay is the most extensive soil of the Fajardo series. It is developed from old high alluvial material and from outwash fans from the adjacent shale hills. The relief is level or gently sloping.

This soil in a cultivated field has a granular brown or reddish-brown friable acid clay surface soil about 9 inches thick, fairly easily penetrated by plant roots and percolating water. The upper few inches of the subsoil consists of distinctly heavier mottled deep-red and brown medium-compact clay, which slightly hinders the percolation of water and interferes with good development of roots. At a depth of about 14 inches the soil material becomes mottled gray, yellow, and red acid clay having about the same physical characteristics as the layer above. This material continues to a depth of more than 5 feet and becomes slightly less compact with depth but is still distinctly mottled. Small angular fragments of shale, some of which are in different stages of weathering, are scattered over the surface and throughout the soil in various quantities. This soil is very acid throughout.

Farmers consider this a moderately good soil for the production of sugarcane, as it yields about 35 tons gran cultura sugarcane, about 30 tons primavera, and 25 tons ratoon. The fertilizer commonly used is 400 pounds of a 12–6–5 mixture at the first application and 400 pounds of sulfate of ammonia as a second application. Elephant grass grows very well on this soil, but grapefruit produces only about 4 boxes to the tree.

This soil is associated with the Río Piedras soils. It occurs near Central Coloso, Río Piedras, Fajardo, and a few other places along the coast. More than 80 percent of the land is used for the production of sugarcane, which is usually planted in furrows. Owing to the moderately compact subsoil, underdrainage is not adequate, especially in nearly level areas, and some drainage ditches are necessary to carry off the excess water.

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Fajardo clay, gray phase.—Areas of Fajardo clay that have such poor drainage that the surface soil is gray or light gray are mapped as Fajardo clay, gray phase. These areas are less productive and more difficult to farm than the typical areas. Other soil characteristics are the same as those of the typical soil. Yields are slightly less on this gray soil, and more attention is required in its cultivation during wet seasons. The land is used almost entirely for the production of sugarcane. Only a small total area is mapped, and nearly all the areas are near Fajardo and Guaynabo.

Fajardo clay, steep phase.—Adjacent to small natural drainageways and eroded gullies are long narrow strips of Fajardo clay that have very steep relief and therefore are mapped as Fajardo clay, steep phase.

Most of this soil occurs south and southwest of Río Piedras. It is used almost entirely for pasture, which supports about two animals to the acre throughout the year. It produces a fairly good stand of malojillo grass. It is valued at about one-fourth as much as the typical soil.

Humacao clay.—Typically developed Humacao clay has a brown acid medium-friable surface soil about 8 or 12 inches thick, which forms large light-brown clods when plowed. The subsoil is heavy moderately compact mottled yellowish-brown and reddish-brown acid clay that is plastic when wet and breaks into large dense clods when exposed by deep plowing. This layer is about 10 inches thick and is underlain by more friable light yellowish-brown gritty sandy clay that is mottled with gray and greenish-gray splotches and seams. Stratified layers of sand, sandy clay, and gravel occur below a depth of 4 feet.

This soil occurs on terraces in the vicinity of Humacao. It is derived from material washed from the coarse-grained granitic materials of nearby hills. It is leached, acid, and low in bases and plant nutrients, and for these reasons cannot maintain a continuously high yearly production of sugarcane, the crop for which it is best suited under present economic conditions. Many farmers have learned that it is more profitable to rest this soil a year or two every 4 or 5 years than to farm it continuously. The rapid-growing grass and weeds, as well as the activity of bacteria, have a beneficial effect on the soil, such as increasing the organic-matter content and improving the soil structure.

Generally this soil is planted to sugarcane or is undergoing a rest period. Yields of sugarcane range from 25 to 60 tons to the acre, depending on the plantings. Gran cultura produces the highest yields, and ratoons the lowest. The principal variety grown is B. H. 10 (12), and P. O. J. 2878 is grown to less extent. From 600 to 800 pounds of fertilizer to the acre is used for each crop. This soil could be improved by applying lime and by planting cover crops.

Humacao clay loam.—Humacao clay loam is developed on rather high terraces within areas influenced by coarse-grained granitic materials. The largest areas are in the vicinity of Humacao.

The surface soil consists of an 8- to 10-inch layer of dark-brown coarsely granular acid clay loam which has a reddish tinge when wet. The material in this layer forms a good tilth when the land is cultivated

at an average moisture condition. This material changes rather abruptly to moderately compact reddish-brown or brownish-red acid massive clay, which grades, at a depth of about 20 inches, into a yellowish-brown acid medium-friable sandy clay substratum. Stratified layers of granite fragments and rounded gravel occur at a depth of about 5 feet.

Humacao clay loam was very productive for the first few years after it was cleared, but, owing to the low fertility of the leached acid granitic material from which it is derived, the sugarcane soon depleted the small amount of accumulated organic matter. Under the present system of cultivation and fertilization, this soil produces from 20 to 30 tons of sugarcane to the acre, depending on the stand and the length of the growing period. Yields could be increased by crop rotation, liming, and manuring. It is not always profitable to rotate the crops, however, as land taxes are high and it is desirable to have a cash crop every year.

Humacao loam.—Humacao loam occurs on nearly flat benches or terraces, derived from granite rocks, in many widely separated parts of the island. In many places the terraces range from 10 to 30 feet above the entrenched stream channels.

The surface soil is characterized by an 8- or 10-inch layer of brown slightly granular acid loam that readily forms a good tilth when cultivated. This layer is underlain by a layer of medium-compact yellowish-brown or reddish-brown clay loam about 8 or 10 inches thick. The material in this layer does not restrict the normal percolation of water and is easily penetrated by plant roots. The upper part of the substratum is mottled red and gray neutral sandy clay loam, which gradually changes, at a depth of 30 inches, to yellowish-brown friable neutral sandy clay loam.

This soil has fairly good physical characteristics for the production of high yields of sugarcane. Owing to its unfavorable chemical characteristics, however, it is low in fertility and therefore not very productive. Sugarcane yields from 30 to 45 tons to the acre under very favorable conditions.

Some areas near Ciales produce fair yields of tobacco and coffee.

Humacao sandy loam.—Humacao sandy loam is inextensive. It occupies a few very small areas, principally southeast of San Lorenzo and in Valle de Yabucao. It is closely associated with the Mayo soils and is similar to them in physical characteristics. It differs from those soils in having a slightly heavier subsoil, and it is a little more productive for truck crops. Humacao sandy loam is considerably lighter in texture in all layers than Humacao loam, and it is also much less productive.

Mayo clay loam.—The 8-inch surface soil of Mayo clay loam consists of light grayish-brown or grayish-brown friable slightly acid nearly structureless clay loam. It is underlain by a friable grayish-brown acid loam or gritty clay loam subsoil. The substratum consists of loose noncoherent friable sandy material containing much quartz.

This soil occurs on alluvial fans and is derived from material washed from the Pandura and associated acid leached granitic soils.

Nearly all of the land is used for the production of sugarcane, which yields fairly well under very favorable conditions.

Mayo loam.—Mayo loam is similar to Mayo clay loam, except that it is more sandy in all layers and is used mostly for the production of minor crops and pasture, which grow as well as on Viví loam or Humacao sandy loam—two soils that are very similar to Mayo loam in physical and chemical characteristics.

Resolución clay loam.—Resolución clay loam is the only soil of the Resolución series occurring in Puerto Rico, and it occupies only one area near the village of Resolución on the Isla de Vieques. This area is a low nearly level alluvial fan formed from material washed from both granitic and tuffaceous rocks and deposited on an old alluvial soil. Parts of this area are lower than areas of Llave loam, but they are never inundated.

Resolución clay loam is characterized by a brown or grayish-brown friable granular neutral clay loam surface soil about 10 inches thick. This layer is underlain by a nearly black very heavy plastic alkaline clay subsoil about 14 inches thick, which rests on brown medium-friable slightly calcareous gritty clay.

This soil has the necessary desirable characteristics for the production of high yields of sugarcane, as it is rather high in organic matter, neutral or alkaline, deep, well drained, and has a subsoil not so heavy as to interfere with rapid penetration of water and roots yet heavy enough to have a large water-holding capacity. The soil occurs in large rather uniform level areas and can be economically farmed with modern machinery. The land is not irrigated, and, as it occurs within an area receiving about 45 inches of mean annual rainfall, sugarcane does not yield more than 20 or 30 tons to the acre. Nearly the entire area is planted to this crop. The sugarcane is planted in deep furrows and seldom is fertilized.

Llave loam.—Llave loam is a productive neutral soil occurring on old nearly level terraces in the western part of Isla de Vieques. This soil is derived from granitic material washed from adjacent granite hills, but, owing to the low average annual rainfall, the soil contains more bases, has a darker surface soil, and is less acid than similar soils on the mainland of Puerto Rico, derived from similar material but receiving more rainfall.

The 8-inch surface soil is dark-brown gritty neutral nearly structureless loam that is readily penetrated by both plant roots and water. It is underlain by a 10-inch layer of slightly compact gritty red alkaline clay that is plastic when wet. The substratum consists of alkaline mottled reddish-brown and gray medium-friable gritty sandy clay.

This soil occupies fairly extensive continuous areas that can be farmed economically with modern machinery. Nearly its entire area is planted to sugarcane, which is very well adapted to this soil, as it is deep, well drained, fairly high in bases, and does not contain harmful quantities of salt. The limiting factor in crop production is water.

Sugarcane seldom yields more than 20 or 25 tons to the acre, but the land is not fertilized for this crop. The general practice is to ratoon the cane several successive years; thus the cost of producing an acre of sugarcane is less than on the mainland. Transportation charges are higher to and from the Isla de Vieques, counteracting the low cost of fertilizing and plowing. The sugarcane is planted in rather deep furrows about 4 feet wide, in order that the roots may have a wide area from which to obtain moisture. The principal variety grown is S. C. 12/4, and some Uba is grown.

Llave sandy loam.—Llave sandy loam is closely associated with Vieques loam in the western part of the Isla de Vieques near Playa Grande. This soil is very similar to Llave loam, but it is more sandy in the surface layer and is not nearly so productive. It is much less extensive than Llave loam. Most of the land is used for the production of sugarcane and minor crops, yields of which depend to a great extent on the annual rainfall.

Arcadia loam.—Arcadia loam occupies a few small irregular-shaped low level alluvial fans in the northwestern part of the Isla de Vieques.

The surface layer, to a depth of 6 or 8 inches, consists of brown semigranular friable neutral gritty loam having a decided purple cast. It is underlain by a 10- to 14-inch layer of purplish-brown medium-plastic massive clay loam or silty clay loam, which becomes more gritty and slightly more reddish brown with depth. This lower layer continues to a great depth and rests on tuffaceous bedrock.

This soil is productive and is used almost exclusively for the production of sugarcane and for pasture, both of which do very well considering the small amount of rainfall received.

Coamo clay.—Coamo clay is a well-drained well-developed deep soil occurring along the terraces of the major streams in the semiarid section, especially near Coamo. Most of it is associated with the Descalabrado soils. The 9-inch surface soil consists of very dark grayish-brown or nearly black granular neutral or alkaline heavy clay. In undisturbed areas there are many wide cracks in this layer, extending from the surface to a depth of 18 or more inches. Recently plowed fields contain many large clods, but they soon slake to a good granular structure after the second or third dashing tropical shower. The subsoil consists of light-brown medium-compact neutral alkaline clay loam to a depth of 30 inches. This horizon resembles a claypan varying considerably in content of clay and degree of compactness. The upper part of the substratum is calcareous light-brown fairly friable clay loam, underlain by stratified layers of loose sand, gravel, and loamy material. The material in this layer contains lime in concretions, in splotches, and in disseminated form.

In some of the very deep cuts, several old soils may be seen, one overlying the other, each with a definite surface soil, subsoil, and substratum.

Most of the areas of Coamo clay occur in positions where irrigation water is not available, and for this reason pasture grasses occupy nearly all of the land. Guinea grass is the predominant grass, and 1½ acres will pasture an ox throughout the year. Grass produced on this soil is very nutritious. During the dry season the grass dries and becomes light brown, but nearly all of it is eaten by the livestock. Within a few days after the rainy season starts the grasses become green again.

Tobacco growing in a few patches of this soil produces from 600 to 700 pounds to the acre during favorable years.

Coamo clay, alluvial-fan phase.—Coamo clay, alluvial-fan phase, occupies a few small gently sloping areas west and southwest of Baños de Coamo. This soil is derived in part from materials washed from limestone hills and in part from the underlying limestone and calcareous tuffs. This soil is as similar to Portugués clay as it is to

Coamo clay, as it has a nearly black granular heavy surface soil underlain by a brown moderately compact or friable clay subsoil. The combined thickness of these two layers is about 20 inches. Below the subsoil is calcareous friable light yellowish-brown material that contains a fairly high percentage of limestone fragments, especially within a short distance from drainageways.

The entire area of this soil is planted to guinea grass, which furnishes excellent range pasture for cattle and horses. The land is as productive as typical Coamo clay.

Coamo silty clay loam.—Coamo silty clay loam is very similar to Coamo clay, but it contains less clay in all layers. Both soils are productive if irrigated, but owing to their position very few areas are irrigated and most of the land is in pasture. A few areas of Coamo silty clay loam are irrigated and produce about 50 tons of sugarcane to the acre. The land is farmed in the same manner as is Paso Seco silty clay loam and in many places is associated with that soil and Descalabrado silty clay. A few areas are planted to tobacco, which yields about 600 pounds to the acre in favorable years.

Areas of Coamo silty clay loam shown on the map by stone symbols are not only the poorest areas of the Coamo soils but constitute some of the most unproductive land in Puerto Rico. Such areas are characterized by numerous rounded boulders scattered over the surface and throughout a mass of brown silty clay loam material that contains a fairly high proportion of sand and gravel below a depth of 4 feet. Such land is used only for pasture or as overnight feeding yards for the work oxen. It has nearly level relief, but the numerous rocks in the surface soil and subsoil limit its use to pasture or trees. It has a very low value.

Coamo silty clay loam, rolling phase.—Coamo silty clay loam, rolling phase, occupies very old eroded terraces in the vicinity of Yauco. Some of the terraces comprise a series of hills, the tops of which are at a common level.

This soil is characterized by a 6- or 8-inch very dark grayish-brown granular alkaline silty clay loam surface soil that is underlain by a brown medium-friable silty clay subsoil about 8 inches thick. The substratum consists of stratified lime-coated gravel and light yellowish-brown loose and friable silty material, which continues downward to a depth of many feet.

This soil is used for sugarcane, pasture, and minor crops. The largest acreage is in beans, pigeonpeas, and corn. Yields are slightly better than on Múcara silty clay loam.

In places lime-coated gravel is exposed on the surface, especially in places where sheet erosion is most active.

Machete clay.—Machete clay is not an extensive soil, but it is very productive, especially when planted to sugarcane, and nearly the entire area is planted to this crop. This soil occurs in places where the average annual rainfall is between 45 and 55 inches, therefore irrigations are necessary for the best production of crops. Central Machete is located on one of the largest areas of this soil (fig. 36).

Machete clay is characterized by a medium-compact dark brownish-red neutral heavy clay surface soil 8 or 10 inches thick, underlain by a dark reddish-brown or red fairly compact neutral clay subsoil about 10 inches thick. The substratum consists of reddish-brown or light brownish-red friable sandy clay loam, which becomes more

friable and sandy with depth. Stratified gravel occurs at a depth of about 4 feet.

This soil is well drained, free from harmful salts, nearly level, deep, and has a subsoil heavy enough to insure a high water-holding capacity. It is also rather high in bases and responds well to fertilizers and irrigations. The surface soil contains a high percentage of clay, therefore cultivation must be done when the moisture content is correct. This soil is more difficult to plow and irrigate than the closely associated Machete clay loam and Paso Seco silty clay.

Much of the land is planted to the B. H. 10 (12) variety of sugarcane, acre yields of which range from 55 to 60 tons of gran cultura, from 40 to 45 tons primavera, and from 30 to 35 tons in ratoons.

Machete clay loam.—Machete clay loam is a well-developed well-drained soil on terraces, many of which extend from the bases of the upland hills to the Caribbean Sea. The largest areas of this soil are in the vicinity of Central Lafayette east of Guayama.

The surface soil in a cultivated field consists of dark brownish-red friable granular neutral loam about 12 inches thick. The lower part of this layer is slightly more compact and heavier in texture than the topmost 3 or 4 inches. The subsoil is dark reddish brown or red somewhat compact neutral clay that averages about 20 inches in thickness and is moderately plastic when wet. It breaks into cubical structural units when dry. The substratum is reddish-brown or brownish-red friable loose sandy clay loam that becomes more sandy with depth. At a depth ranging from 5 to 6 feet are stratified beds of water-worn gravel. Many pieces of gravel occur throughout all the soil layers, but they do not interfere with cultivation or lower the value of the soil.

This is one of the most productive soils in the southeastern part of the island. Nearly all of it is cultivated to sugarcane, and when the land is properly irrigated, fertilized, and cultivated it produces from 4 to 5 tons more to the acre than Machete clay.

Primavera plantings seem to be the best for this soil, and yields of 12 to 14 percent sugar at 96-percent purity are not uncommon.

Alkali or salt is not a limiting factor in crop production on this soil. During the period from 1930 to 1935 this land was valued at about $400 an acre.

Machete loam.—Machete loam occupies a few small areas east of the mouth of Río Jacaboa in the southeastern part of the island. It differs from Machete clay loam in that it is more friable, contains less silt and clay, and has a larger content of sand. This soil occurs in areas receiving slightly more rainfall than the largest areas of Machete clay loam. Most of Machete loam is used for the growing of sugarcane. The land is not irrigated, but the production of sugarcane would be increased by irrigation. Most areas are situated so that irrigation would be expensive, and the farmers prefer to obtain lower yields without irrigation. The sucrose content usually is high on this soil, but the yields are much less than on irrigated Machete clay loam. The principal varieties of sugarcane grown are P. O. J. 2878 and Uba, which yield from 25 to 35 tons to the acre without irrigation.

Machete loam, steep phase.—Areas of Machete loam occurring along drainageways that have steep relief are mapped as a steep phase. This soil is used only for pasture, owing to unfavorable broken relief. Goats and oxen on picket ropes consume the grass, which is nutritious

and luxuriant. Guinea grass and cerrillo grow equally well on this soil. As mapped, this soil includes a few small areas with a surface soil of clay loam texture.

Vives clay loam.—In many places Vives clay loam is closely associated with Machete clay loam. These two soils are similar in many respects, as they are well-drained nearly flat deep soils occurring on terraces associated with the Guayama soils.

Vives clay loam is characterized by a very dark grayish-brown or nearly black loose granular surface soil about 12 inches thick, underlain by a brownish-red medium-compact alkaline clay subsoil about 14 inches thick, which is plastic when wet. The substratum consists of friable red or reddish-brown gravelly sandy clay loam, which becomes more friable and more gravelly with depth.

This soil is nearly as productive as Machete clay loam, and the two soils should respond to the same management. Nearly the entire area of Vives clay loam is used for the production of sugarcane. Gran cultura cane yields from 50 to 60 tons to the acre, primavera from 40 to 45 tons, and ratoon from 30 to 35 tons.

Vives clay loam, colluvial phase.—Areas of Vives clay loam that occupy the long gentle slopes between the Vives and Guayama soils are mapped as a colluvial phase of Vives clay loam. The profile of this soil is nearly identical with that of the typical soil, but, owing to its higher position, not all of it is irrigable. Therefore, a much larger proportion of it is in pasture than of the typical soil. Also, as it is steeper, it has a thinner surface soil and is less productive. It yields from 5 to 10 tons to the acre less than the typical soil. Some areas contain a few fairly large rocks that probably have rolled down from the adjacent reddish-brown hills.

Vives clay loam, steep phase.—A few small areas of Vives clay loam that occupy the slopes adjacent to streams and gullies are mapped as a steep phase of the typical soil. This soil differs but little from the steep phase of Machete loam, except that the surface soil is dark grayish brown and it has a higher content of clay. The subsoil and substratum of the two soils are nearly identical. The steep Vives soil is used almost entirely for pasture, and the grasses produced are as thick and nutritious as those produced on Machete loam, steep phase.

Vives loam.—Vives loam is very similar to Vives clay loam, except that it is more sandy in all layers, is more easily cultivated, and is less productive.

This is an inextensive soil occurring in several small areas near the coast between Guayama and Maunabo. Nearly all of it is used for the production of sugarcane, which yields from 40 to 50 tons to the acre in gran cultura when the land is well fertilized and contains sufficient moisture.

Vives sandy loam.—Vives sandy loam is one of the least extensive soils of this series and occurs principally in the vicinity of Río Jacaboa and north of Punta Viento. This soil is associated with Vives loam, but it has had some influence from granitic material, which is responsible for the sandy texture.

Vives sandy loam differs from the other Vives soils in that it is more sandy in all layers, is slightly more acid, and is much less productive. Very little of the land is irrigated. Nearly all of the area is planted to sugarcane, yields of which range from 25 to 30 tons to the acre.

COMPACT SOILS OF THE TERRACES AND ALLUVIAL FANS

The compact soils of the terraces and alluvial fans include 26 soil types and phases of the Fraternidad, Paso Seco, Fé, Santa Isabel, Teresa, and Candelero series. All these soils, with the exception of those of the Candelero series, occur in the arid or semiarid sections and are derived mostly from materials washed from limestone, tuffaceous rocks, and shale. They range in elevation from a few feet to about 200 feet above sea level. These soils are deep, nearly flat, alkaline or calcareous, high in bases, and very productive. The surface soils are distinctly granular and range from light brown to very dark grayish brown or nearly black, depending on the amount of the average annual precipitation received since the material was deposited. The greater the rainfall the denser the grass vegetation and, therefore, the darker the soil color. Even within a distance of 4 or 5 miles in a north-south direction, the average annual rainfall decreases 15 or 20 inches, which has a decided effect on the soil color.

Typically, the Fraternidad soils occupy long gentle slopes that extend from the bases of volcanic and limestone hills to, and in many places overlapping, the soils of the coastal lowland and river flood plains. These soils are derived in part from residual materials. They have brown or very dark grayish-brown heavy granular calcareous surface soils underlain by compact yellowish-brown very heavy calcareous clay subsoils containing numerous lime concretions. The substratum is light yellowish-brown calcareous clay which is more friable than the subsoil and contains numerous sharp angular rock fragments. Most of these soils occur in the southwestern part of the island.

Both internal and external drainage are good. The natural drainage is made effective by small deeply entrenched intermittent watercourses which are flooded to capacity after the sudden torrential showers that occur during the rainy season. Within 10 or 12 hours after a storm, the water recedes and the channels become dry.

The Paso Seco soils are very similar in position and physical characteristics to the Fraternidad soils, but they do not contain free lime. The Paso Seco soils occur both on terraces and on alluvial fans but in few places overlap the coastal lowlands or river flood plains.

The Fé soils differ from the Fraternidad soils in that they have distinctly pinkish-brown or light purplish-brown subsoils and a purplish-brown or pinkish-brown substratum. They are derived from old alluvial material and in many places have stratified beds of sand and gravel below a depth of 4 feet. In several areas, notably northeast of Coqui and northwest of Laguna de Guánica, numerous mounds (tumors) occur on the poorly drained areas of this soil. Most of the mounds range in height from 3 to 4 feet and in length from 10 to 15 feet, protruding from the level land. The watery colloidal clay in suspension within the mound is capped with an 8- to 12-inch layer of hardened clay, with the exception of a long narrow continuous crack extending lengthwise over the top of the mound. From this crack, water and soil charged with sodium carbonate ooze during the rainy season or when the pressure of the underground water on its way to the ocean is great enough to be forced upward to the surface. The sticky ooze of many of these tumors is more than 15 feet deep, and livestock sometimes sink into it. Many of these spots are fenced, but others are in their natural condition. Cattails grow nearby on the less salty areas.

The Santa Isabel soils are light brown or brown throughout the profile, and the subsoils in general are of a yellowish-brown shade. The surface soils are medium friable, alkaline, and granular. The subsoils are very compact, limy, and columnar. The substrata are friable and are stratified with sand and gravel beds below a depth ranging from 4 to 5 feet. These soils are similar to the Fraternidad soils except that they are more definitely derived from old alluvium as shown by the underlying gravelly layers.

Comparatively speaking, the Teresa soils are poorly drained Santa Isabel soils and generally have a much higher content of alkali.

Nearly all of the irrigated area of these soils is planted to sugarcane, which yields from 30 to 100 tons to the acre. Most of the sugarcane is planted in furrows about 4 feet wide and irrigated from 10 to 16 times, depending on the length of the growing period and the amount of rainfall received. The principal sugarcane varieties grown are B. H. 10 (12), P. O. J. 2878, and C. O. 281. Probably more than 80 percent of the sugarcane grown is B. H. 10 (12). The most common fertilizers applied are about 300 pounds of 12–8–4 as a first application and 300 pounds of ammonium sulfate as a second application.

Areas of these soils that are not affected with alkali and are not irrigated produce a very good quality of guinea grass, Bermuda grass, and Mexican bluegrass. The carrying capacity of the pasture is about one animal an acre a year. Some areas are planted to field corn, which produces about 20 bushels to the acre.

The areas affected with alkali are valued at about one-tenth of the value of the nonalkali areas and are used only as feed lots and pastures for the work oxen on the sugar centrals. The alkali-affected areas produce a halophytic vegetation and such grasses and trees as are tolerant to salt. Bermuda grass and Mexican bluegrass will grow unless the salt content is high.

Soils of the Candelero series occur in the humid east-central part. They are derived from material washed from hills composed of coarse-grained quartz diorite rocks. These soils are gray, leached, acid, gritty, low in bases, and low in plant nutrients. They have very compact nearly impervious gray heavy subsoils, which restrict the development of roots and the percolation of water. The water rapidly penetrates the surface soil but flows laterally along the top of the subsoil to seepage spots and drainageways. At a depth ranging from 20 to 60 inches is the substratum of partly disintegrated quartz rocks.

The Candelero soils are used extensively for the production of sugarcane, but yields are low, even when applications of 700 or 800 pounds of fertilizer are used and the precipitation is adequate. Most of the sugarcane grown is B. H. 10 (12), which is planted in furrows or shallow banks.

Fraternidad clay.—Fraternidad clay occupies many of the long gently sloping alluvial fans between Boquerón and Guayanilla, especially near Fraternidad. Many areas extend from the bases of the upland hills to the Guánica soil of the coastal lowlands, as near Laguna de Guánica.

When dry this soil is identified readily by the numerous deep wide cracks throughout the brown dense calcareous very heavy clay surface soil. Below the 7- to 10-inch surface soil is yellowish-brown plastic stiff calcareous clay, which continues downward to a depth of 15 to 20

inches. Below this layer is the zone of maximum lime accumulation, in which the soil material consists of light yellowish-brown fairly friable clay that changes but little with depth except that it contains many rock fragments and gravel at a depth of about 4 feet. Throughout all layers rock fragments are conspicuous, but they do not interfere with plowing or subsequent cultivation.

A large proportion of this soil is not irrigated, and it is used as range land for the large cattle ranches and dairies. The principal grasses are guinea, horquetilla, and Bermuda. Guinea grass provides the best pasture. In average years the grasses on 1 or 1½ acres will maintain an ox throughout the year. Generally the cattle are pastured on this soil during the fall, winter, and spring, as the grass usually dries during the summer. The cattle then are shifted to fresh pastures in the humid sections.

Corn is grown on a fairly large proportion of the nonirrigated land. It yields from 15 to 20 bushels an acre.

Sugarcane is grown exclusively on the irrigated areas. It yields about 50 or 60 tons to the acre, depending on the amount of irrigation water available. In most places the water is pumped from wells or from the nearby lagoons, and during most years the supply is not adequate. This soil contains some salt in the subsoil, which will increase if the land is irrigated and not adequately drained. As the soil is very intractable, it is drained with difficulty.

Fraternidad clay as mapped varies considerably in physical characteristics. In some places it has a very plastic surface soil and is very similar to Ponceña clay. In other places it has a very small content of free lime and therefore is very similar to Paso Seco clay. In some places it has a purplish-brown subsoil very similar to the subsoil of Fé clay. In areas adjacent to some of the streams, stratified gravel beds lie at a depth of about 5 feet, as in areas of Santa Isabel clay.

Fraternidad clay, shallow phase.—Areas of Fraternidad clay that are adjacent to intermittent streams and contain unusual quantities of assorted valley-fill gravel at a depth of about 2 feet are mapped as Fraternidad clay, shallow phase. This soil occupies only a very small area and is used mostly for pasture. It is not nearly so desirable as the typical soil and if irrigated would require excessive quantities of water in order to produce fairly high yields of sugarcane. Pasture grass grows abundantly, and the carrying capacity of the land is greater than that of the soils on the hills.

Fraternidad clay, imperfectly drained phase.—The imperfectly drained phase of Fraternidad clay occurs in concave areas where local drainage is lacking. Therefore aeration and oxidation of the soil are limited. The surface soil is similar to that of the typical soil, but in most places the subsoil and substratum are more moist and contain gray and rust-brown mottled streaks and splotches.

Many areas of this soil are planted to sugarcane which yields from 20 to 25 tons to the acre without irrigation if the rainfall for the season is above normal. The soil produces a very good quality and quantity of malojillo grass. The land would be as productive for sugarcane as Aguirre clay if it were properly drained and irrigated.

Fraternidad clay, colluvial phase.—A few small areas of Fraternidad clay occupy moderately sloping positions adjacent to streams or hillsides and are mapped as Fraternidad clay, colluvial phase. Physically this soil is identical with the typical soil, and probably the two soils

vary but slightly in chemical characteristics. The colluvial phase occurs in two widely separated areas, one near Cabo Cabezas de San Juan near the northeastern point of the island and the other in the southwestern part near Laguna de Guánica.

This soil is not irrigated and is used only for pasture or for the production of corn. It is high in organic matter and bases and would be very productive if water were available.

Fraternidad clay loam.—Fraternidad clay loam occurs only in a few small bodies southeast of Fraternidad. It differs from Fraternidad clay in that it has been influenced by gritty material washed from adjacent limestone hills or deposited by overflows from nearby streams. It has nearly the same agricultural use as Fraternidad clay and is considered as productive as that soil. Nearly all areas are in guinea grass pasture, which produces sufficient grass during the rainy season to pasture two animals to the acre.

Paso Seco silty clay.—Paso Seco silty clay is one of the highly productive soils occurring throughout the semiarid section, from Arroyo to Boquerón, especially near Paso Seco, as well as on the Isla de Vieques. It occupies alluvial fans or terracelike positions at elevations sufficiently high for the subsoil to be many feet above ground-water level. This soil therefore is well drained and in few places is affected with alkali or salt.

Paso Seco silty clay is characterized by a brown medium-friable granular alkaline silty clay surface soil 10 or 12 inches thick that is high in organic matter and plant nutrients. When very wet this layer is difficult to cultivate, although it absorbs water readily and cultivation is not delayed long after an average rain. The subsoil is brown or yellowish-brown cloddy medium-compact alkaline heavy clay, which grades, at a depth ranging from 26 to 30 inches, into slightly more friable yellowish-brown alkaline silty clay, which is underlain, at a depth of 4 feet, by stratified alkaline sandy and gravelly materials.

This soil has physical and chemical characteristics that make it well adapted for the production of sugarcane. It has a deep surface soil that is high in organic matter, granular, and alkaline. The subsoil has a large water-holding capacity but is not too compact to interfere seriously with the penetration of plant roots. The lower part of the deep substratum contains sufficient friable sandy material to give adequate internal drainage and to prevent the serious rise of salt by capillary action. These desirable characteristics, combined with sufficient irrigation, good management, and a nearly ideal climate, make this soil very productive for sugarcane. Gran cultura sugarcane yields from 70 to 80 tons an acre year after year, and primavera plantings yield slightly less.

This soil occurs in rather uniform large areas, and modern up-to-date machinery can be used efficiently. Nearly the entire area is devoted to sugarcane.

In a few areas considerable gravel or small stones are on the surface and throughout the soil, and such areas are less valuable and require more irrigation than the typical soil. The few bodies of this soil occurring where the average annual rainfall ranges from 45 to 55 inches are slightly darker and higher in fertility; therefore they are more desirable than the typical areas, which receive less than 45 inches of rainfall.

Paso Seco clay.—Paso Seco clay is not extensive, as it occupies only a few areas in the southwestern part, mainly on the alluvial fans in Valle de Lajas.

This soil differs from Paso Seco silty clay in that it has a higher content of clay in the surface soil and is more difficult to plow. It occurs in areas that receive very small amounts of precipitation and limited irrigation. Most of it is used as range land for oxen and range cattle. The grass produced is nutritious and dense, but it becomes dry and brown during the long dry winters. This soil would be equally as productive as Paso Seco silty clay if it were irrigated and well managed.

A few areas in which there are excessive quantities of rock fragments on the surface and throughout the soil profile are shown on the soil map with stone symbols. Such areas are less productive than the typical soil and are rather difficult to plow or to cultivate.

Paso Seco silty clay loam.—Paso Seco silty clay loam differs from Paso Seco silty clay principally in the lighter texture of the surface soil, which affects the east of cultivation and renders it more desirable than the silty clay. The agricultural use and production of the two soils are similar.

The surface soil consists of a 9- to 13-inch layer of brown granular alkaline fairly friable silty clay loam. This changes abruptly to moderately compact yellowish-brown alkaline clay, which grades downward into more friable yellowish-brown alkaline silty clay loam at a depth of about 30 inches. This layer is underlain by stratified sand and gravel.

Areas of this soil in the semiarid sections have a darker surface soil and are slightly more desirable than areas in the arid sections. The few areas shown on the map with gravel symbols are more droughty than the typical areas and therefore are much less productive. Irrigation canals should be lined through the areas having the gravelly layer, otherwise much water will be lost through seepage.

Paso Seco silt loam.—Paso Seco silt loam occupies a few areas east of Ponce on the level alluvial fans fairly near the sea. This soil is less productive than Paso Seco silty clay or Paso Seco silty clay loam, but it has the advantage of being easier to plow and cultivate. The physical and chemical characteristics are so similar to those of Paso Seco silty clay loam that, if allowance is made for texture, the description of one soil fits the other.

Paso Seco loam.—Paso Seco loam is a deep-brown productive soil occurring in a few places in the semiarid section, chiefly near Paso Seco, on alluvial fans and in terracelike positions.

The surface soil consists of a 10- or 12-inch layer of dark-brown coarsely granular neutral or slightly acid loam. This grades downward into more compact brown or yellowish-brown neutral heavy silty clay or silty clay loam, which has a high water-holding capacity but does not prevent the rapid penetration of plant roots. This layer changes at a depth of about 30 inches to more friable yellow alkaline silt loam, which is underlain at a depth of about 4 feet by stratified sands and gravel.

This soil is easily plowed and cultivated, but it is not so productive as Paso Seco silt loam when the same amount of fertilizer is used. It is a productive soil and is used exclusively for the production of sugarcane, which yields from 55 to 70 tons of gran cultura cane to the

acre. The sugarcane is planted in furrows about 4 feet apart, fertilized with 400 pounds of 12–8–4 and later with 400 pounds of ammonium sulfate, cultivated 3 or 4 times, irrigated from 10 to 14 times, and then harvested.

Areas of this soil that occur in terracelike positions near Arroyo, where the average yearly rainfall is about 65 inches, are considerably more acid than other areas. Such land would respond to applications of lime in addition to the fertilizer.

Fé clay.—Fé clay is associated with the other soils of the alluvial fans in the semiarid sections from Boquerón to Guayama. The Fé soil is identified readily by its pinkish-brown or purplish-brown subsoil.

The surface soil in a cultivated field is grayish-brown or dark grayish-brown granular calcareous clay, very plastic when wet and either granular or cloddy when dry, depending on the moisture condition of the soil when plowed. The subsoil, to a depth of approximately 20 inches, is light pinkish-brown or purplish-brown plastic calcareous medium-compact columnar clay. It is underlain by a lighter colored but heavy substratum containing many splotches of lime. This material grades downward to stratified sand and gravel deposits that are very calcareous.

This soil is somewhat similar to Paso Seco silty clay, but it is not so productive, and some spots are affected with salts. Cultivation of the two soils is similar, and the fertilizers used and sugarcane varieties planted are the same. Yields of sugarcane, the only cultivated crop grown, range from 30 to 60 tons an acre.

Some areas that have an unusually large number of angular small stones and pieces of gravel on the surface and throughout the soil profile are shown on the map with gravel symbols. These areas are not so desirable nor so productive as the typical areas.

Fé clay, imperfectly drained phase.—Areas of Fé clay that have a high water table are shown on the map as an imperfectly drained phase. This soil is closely associated with the typical soil. It occupies slightly lower positions than the typical soil, and many areas of it are affected with salts accumulated under the influence of seepage of irrigation waters.

The high water table, which in places is within a few feet of the surface, prevents the lower part of the subsoil and the substratum from becoming well aerated. Therefore, the soil is mottled gray and rust brown, showing poor oxidation. Areas of this soil that do not contain harmful quantities of alkali salts produce a higher tonnage of sugarcane to the acre than the typical soil, but the sucrose content is lower. The principal sugarcane varieties grown are B. H. 10 (12) and C. O. 281, and both do very well on this heavy plastic soil. The land requires drainage, irrigation, fertilization, and thorough cultivation, in order to produce 60 tons of sugarcane to the acre.

Some areas of this soil, shown on the map with gravel symbols, have considerable quantities of sharp angular many-colored rocks and rock fragments scattered on the surface and throughout the soil profile. They are much less productive than the typical soil. Most of them are affected with a fairly high content of sodium carbonate and are nearly valueless for the production of sugarcane. Bermuda grass and halophytic vegetation grow if the content of salts is not in excess of about 1½ or 2 percent. Some areas are barren of vegetation,

and the land has the characteristic pitted appearance of land that has long been affected with black alkali, or sodium carbonate.

Santa Isabel clay.—Santa Isabel clay occupies more widely separated parts of the semiarid sections than any other soil of the Santa Isabel series. It occurs on the nearly level well-drained alluvial fans and in terracelike positions along the southern coast from a point near Arroyo to Boquerón. It also occurs in St. Croix and probably in some of the other islands of the West Indies that have an arid climate and alluvial-fan materials washed from limestone or from calcareous tuffaceous hills.

Santa Isabel clay is characterized by an alkaline granular heavy clay surface soil about 12 inches thick. This layer is plastic and sticky when wet and ranges in color from light brown to very dark grayish brown or nearly black, depending on the amount of average annual rainfall. The areas that continually receive the greatest rainfall are the darkest. The subsoil is very heavy compact brown calcareous plastic clay ranging from 10 to 12 inches in thickness. It is underlain by more friable yellowish-brown or olive-drab highly calcareous silt loam, which becomes more friable and lighter in texture with depth. In many places, stratified sands and gravel are present below a depth of 4 feet. This soil has the necessary characteristics that render it well adapted for the growing of sugarcane, and nearly its entire area that is irrigated and is not affected with harmful soluble salts is used for this crop.

This is one of the valuable soils along the southern coast, and land prices ranging from $500 to $650 an acre were not uncommon for the best areas during the period 1930–36. This soil is not so desirable as the best areas of the San Antón soils, because the subsoil is too compact for best penetration of roots or percolation of water, and in addition the soil is much more likely to be affected with soluble salt.

B. H. 10 (12) and C. O. 281 are the principal varieties of sugarcane grown, but P. O. J. 2878 should produce very good yields. The average acre yield of sugarcane is about 70 tons for 18- or 20-month gran cultura plantings. Other plantings yield much less. Usually from 600 to 800 pounds of fertilizer is applied, and the land is irrigated from 12 to 16 times for gran cultura plantings. The sugarcane is planted in furrows, and laterals are used to deliver the water from the ditches to the plants. This soil is difficult to plow and should be worked when it is neither too wet nor too dry. The gyrotiller (a rotating plow) should prove very effective in this soil, as the heavy compact subsoil should be made more friable but should not be brought nearer to the surface, especially if it contains alkali.

Santa Isabel silty clay loam.—Santa Isabel silty clay loam is similar to Santa Isabel clay, but it differs from that soil in that it contains a larger proportion of silt and less clay. It is slightly easier to plow and cultivate than the clay soil and for this reason is more desirable.

This soil is closely associated with the other Santa Isabel soils on the nearly level alluvial fans along the southern coast from a point near Guayama to a point near Guánica. The agricultural use of this soil is nearly the same as for Santa Isabel clay, and nearly all of the land is used for the production of sugarcane, except in places where the content of salt in the surface soil is greater than 0.2 percent.

Santa Isabel loam.—The 10- or 12-inch surface soil of Santa Isabel loam consists of brown, dark-brown, or very dark grayish-brown distinctly granular medium-friable loam or silt loam. It is abruptly underlain by a yellowish-brown calcareous compact heavy clay loam or clay subsoil, which grades downward into friable olive-drab or slightly yellowish brown calcareous silt loam and stratified layers of sand and gravel.

This soil is closely associated with the lighter textured soils of the San Antón series along the southern coast at elevations of less than 100 feet above sea level, and nearly the entire area is used for the production of sugarcane, which yields equally as well as on Santa Isabel clay.

Teresa clay.—Teresa clay is the most poorly drained soil in the group of compact soils of the terraces and alluvial fans. It is associated with Santa Isabel clay mainly from Ponce to Central Aguirre and is similar to that soil, but the water table occurs at a depth ranging from 20 to 36 inches from the surface.

A much larger proportion of this soil than of Santa Isabel clay is affected with alkali, and many ratoon sugarcane fields and a few gran cultura plantings are affected with lime chlorosis, especially in areas southeast of Central Cortada.

The 10-inch surface soil consists of brown or dark grayish-brown granular alkaline or calcareous very heavy clay that is plastic and sticky when wet. Large hard clods are formed when the land is plowed when either too wet or too dry. The subsoil consists of a 10- or 12-inch layer of yellowish-brown calcareous plastic columnar clay containing many lime concretions and splotches of disseminated lime. The material in this layer rather abruptly changes to mottled grayish-brown, yellowish-brown, or olive-drab friable calcareous clay that is wet most of the time, especially during the rainy season.

Areas of Teresa clay not affected with alkali are used almost exclusively for the production of sugarcane, which yields from 35 to 60 tons to the acre, depending on the amount of water available and the kind of planting. This soil requires drainage, irrigation, fertilizer, and careful management for successful crop production. The areas affected with alkali are valued at less than one-tenth of the value of the alkali-free areas, and they are used only as pasture and feed lots for the work oxen.

Teresa silty clay loam.—Teresa silty clay loam is very similar to Teresa clay, but it has a lower content of clay and a higher proportion of coarser material in all layers. It occurs on the slightly lower flats of the alluvial fans from Ponce to Salinas.

This soil is about equally as productive as Teresa clay, and it is more easily cultivated. It is considered a good soil for sugarcane, except where it is impregnated with salt. The 10-inch surface soil consists of medium-friable dark-brown or brown alkaline granular silty clay loam that is very plastic and sticky when wet. The material in this layer abruptly changes to brown or yellowish-brown columnar compact calcareous heavy clay about 12 inches thick containing numerous lime and iron concretions. At a depth ranging from 20 to 30 inches is the slightly mottled yellowish-brown and rust-brown wet plastic silty clay loam substratum, which gradually becomes wetter and lighter in texture with depth.

The columnar compact subsoil is not readily penetrated by plant roots or water. In most places the ground water lies immediately below this layer, and water will rise to a point within a few inches of the surface in auger holes when the subsoil is penetrated.

Teresa loam.—Teresa loam occupies a few very small areas near Santa Isabel and Ponce. It is not an important soil because of its small extent. It differs from Teresa silty clay loam in that it is more friable and much lighter in texture in all layers, and it differs from Santa Isabel loam in that the water table lies within a few feet of the surface.

Teresa loam is easily cultivated and prepared for sugarcane, the crop that occupies nearly 100 percent of its area not affected with alkali. Yields are equally as high as on Santa Isabel loam and nearly as high as on San Antón loam.

Candelero loam.—Candelero loam occurs on sloping alluvial fans formed by outwash from the quartz diorite hills in the east-central part of the island, principally south of Humacao near Río Candelero. Although not extensive, it has a larger total area than any other soil of the Candelero series. It is easily identified by its excessively leached friable gray gritty surface soil and compact gray gritty clay subsoil.

In a cultivated field the surface soil, which extends to a depth of about 10 inches, consists of light-gray friable nearly structureless acid loam containing many fine angular quartz gravel and granite fragments. This layer rests on the upper part of the subsoil, which is light-gray medium-compact gritty acid clay loam containing some yellowish-brown gritty clay material. At a depth of about 15 inches, this layer grades into the lower subsoil layer, which consists of exceedingly stiff compact acid mottled dark-gray and yellowish-brown clay. The substratum, from a depth of about 25 to more than 45 inches, is pale greenish-gray colloidal clay streaked and mottled with yellowish-brown gritty clay. It is very stiff when wet and exceedingly hard when dry.

Candelero loam is used for the production of sugarcane and minor truck crops. Yields are low, owing to the low organic-matter content, low bases, acid condition, and the nearly hardpan condition of the subsoil. During the rainy season water penetrates to the subsoil and flows laterally rather than downward, and shallow drainageways are necessary for the removal of excess water. During dry periods the surface soil and subsoil dry so quickly that crops suffer from lack of moisture.

Sugarcane yields from 20 to 30 tons to the acre during very favorable years and with heavy applications of fertilizer. This soil is valued at prices ranging from $30 to $50 an acre, as compared with $300 for good Toa loam.

A few small areas of this soil occurring in the bottoms of small U-shaped ravines have poorer natural drainage than average areas, but with artificial drainage the areas are nearly the same.

Candelero loam, shallow phase.—Candelero loam, shallow phase, includes areas closely associated with Candelero loam but occurring on more sloping relief adjacent to the uplands. The soil is influenced to considerable extent by the underlying partly disintegrated granite

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rock. This soil is derived in part from colluvial and alluvial materials and in part from residual material.

The surface soil is bleached pale-gray acid friable loam to a depth ranging from 4 to 10 inches, depending on the slope and the amount of surface wash that has taken place owing to improper management. This layer is underlain by heavy compact acid gray or yellowish-gray gritty clay loam or gritty clay resting on partly disintegrated granite rock at a depth ranging from 20 to 36 inches.

A few small areas, shown on the map with gravel symbols, have an excessive quantity of quartz gravel on the surface and throughout the upper part of the profile. These areas are of very low productivity and are somewhat difficult to cultivate and farm.

This is a poor agricultural soil, as it becomes saturated with water during average rainy seasons and is droughty during average dry seasons. The subsoil is nearly impervious to both roots and water. The surface soil is low in fertility and erodes unless it is carefully managed. The land is used for pasture, minor crops, and sugarcane in about equal acreages.

Candelero clay.—Candelero clay occupies a few very small areas. One is about a mile west of the mouth of the Río Candelero, and one is about a mile west of Maunabo.

This soil is similar in profile characteristics to Candelero loam, but it has a higher content of silt and clay in all layers. It is slightly more productive for sugarcane and less productive for minor crops than is the loam member. It is used nearly exclusively for the production of sugarcane.

Candelero clay, shallow phase.—The shallow phase of Candelero clay also is inextensive. One of the largest areas is about 1½ miles northwest of Playa de Yabucoa along the foot slopes of the coarse-grained granitic hills.

This soil differs from Candelero loam, shallow phase, in that it contains a much higher proportion of silt and clay in all layers and is more productive for sugarcane. It requires shallow drainage systems for the removal of excess water during the rainy season. Sugarcane is planted in furrows, and nearly the entire area is planted to this crop, which, under good management, yields from 25 to 30 tons to the acre in favorable years.

Candelero sandy clay loam.—The 8- to 10-inch surface soil of Candelero sandy clay loam in cultivated fields consists of gray or bleached yellowish-gray acid medium-friable sandy clay loam. It is underlain by a slightly mottled gray and rust-brown gritty but very compact acid clay subsoil about 20 inches thick. This layer gradually changes to pale greenish-gray stiff but gritty clay similar to the substratum of Candelero loam, the soil it most closely resembles. These two soils are closely associated in the eastern part of the island on alluvial fans that have been formed from materials washed from coarse-grained granitic hills. As neither soil is high in organic matter and both have subsoils too heavy for good penetration of roots and water, they are only fairly productive. Sugarcane occupies a slightly higher proportion of the area of Candelero sandy clay loam than does any other crop. B. H. 10 (12) is the principal variety of sugarcane grown. It yields about 30 tons to the acre from gran cultura plantings when the land is well fertilized and properly managed.

Many small areas occurring along small streams have a decided mottled gray and rusty-brown color in the subsoil, indicating poor drainage or seepage from adjacent areas. They are not shown separately on the soil map. With a good system of artificial drainage the included soil is identical with the typically developed soil.

Candelero sandy clay loam, shallow phase.—Candelero sandy clay loam, shallow phase, differs but slightly from Candelero loam, shallow phase, both in soil characteristics and in agricultural use. It is heavier in texture and therefore more difficult to till than the loam. It probably has been eroded to greater extent than Candelero loam, and some of the heavy clay subsoil has become mixed with the surface soil, thereby imparting a heavier texture.

This soil requires considerable nitrogen in the fertilizer in order to produce plants with a good green color. Lime and manure would help in increasing the productivity of the land.

Candelero sandy clay loam, broken phase.—Candelero sandy clay loam, broken phase, includes the long narrow strips of steep land, adjacent to small natural drainageways and eroded gullies within the alluvial fans, that have been derived from coarse-grained granitic material. This soil is used almost exclusively for pasture and adds but little to the value of a farm.

Candelero sandy loam.—Candelero sandy loam occupies a few small areas in the valley near Caguas. This soil has developed in place, through the disintegration and weathering of small exposed outcrops of granite rock. It occupies alluvial-fan positions ranging from 100 to 200 feet above sea level.

This soil has a deeper and sandier surface soil than Candelero loam, but in other respects the two soils are very similar. Nearly all of the sandy loam is used for sugarcane and pasture. Yields are about the same as on Candelero loam.

SOILS OF THE COASTAL PLAINS

The soils of the coastal plains do not include the steep shallow soils of the coastal plains derived from Tertiary limestone, as those are included with the soils of the uplands.

The soils of this group have many characteristics in common. They are deep, nearly level, only reasonably fertile, and range from neutral to strongly acid. They range in texture, however, from sand to clay and in color from red to yellow and from nearly black to nearly white. The dominant color is red. They have been subdivided according to physical characteristics into four groups, which also group the soils that are adapted to specific crops. The four subdivisions are compact soils, friable soils, very friable soils, and loose soils.

COMPACT SOILS OF THE COASTAL PLAINS

The compact soils of the coastal plains are more difficult to farm than any other soils on the island because of their heavy stiff impermeable subsoils. Included in this group are soils of the Sabana Seca and Caguas series, which are grayish-brown soils probably derived from old marine deposits and a mixture of materials washed from the uplands; the Almirante soils and the Vega Alta soils, both derived from hard Tertiary limestone; and soils of the Islote series, derived from sandy limestone.

These soils occur on the northern coastal plains and inland valleys. Most of the areas, however, do not extend more than 5 miles back from the seashore, and all have nearly level or undulating relief. Most of these soils receive an annual rainfall ranging from 60 to 75 inches, which is sufficient for the production of subsistence crops, but some of the sugarcane fields and citrus trees are irrigated.

The principal crops grown on these soils are sugarcane, followed by minor crops, pineapples, and grass. The crop yields are below the average for the coastal plains and much lower than the average for the alluvial soils.

The soils in this group range in elevation from a few feet to about 500 feet above sea level. The mean annual rainfall ranges from about 50 inches near Lajas and Isabela to 75 inches near Bayamón and Florida. Some of the soils occur in small areas from one end of the north coast to the other, a distance of more than 100 miles. Within this distance there is some variation of the chemical characteristics, especially in the acidity and in the amount of leaching that has taken place in the profile, owing to the soil moisture. Generally speaking, the areas receiving 50 inches of average annual rainfall have a pH value of about 6.0 and are not leached to so great an extent as are those receiving 76 inches of rainfall and having a pH value of 4.5.

The surface soils are plastic and stiff, and cultivation must be done at about the correct moisture content. These soils are sensitive to drought, and yields are greatly reduced if rains are long delayed during the growing periods. The soils respond well to irrigation, provided they do not become too wet. Cultivation is more costly on these soils than on the other coastal-plain soils, and good management and heavy applications of fertilizers are necessary for even moderate returns.

Under present conditions, the sugarcane variety S. C. 12/4 is the best crop grown, as it seems to have sharper pointed roots, which can more readily penetrate the stiff heavy subsoil for plant nutrients and water. The subsoil, however, is so stiff and exerts so much pressure when it expands and contracts, or fissures, at the extreme of moisture content that nearly all of the plant roots that penetrate it are greatly deformed. Some are flat, others are twisted, and others have been squeezed nearly in two. This greatly reduces the efficiency of the roots to supply the cells of the plants with water and plant nutrients. The plant roots have a tendency to develop in the gray splotches of the subsoil rather than in the red or brown mottled areas, as the gray material is slightly softer and has a higher content of alumina and clay and less sand and iron.

The soils in this group should be greatly improved by deep knifing or by plowing with a gyrotiller that would break up the upper part of the heavy stiff subsoil. After the subsoil has once been made mellow, it will not run together and again become compact nearly so quickly as do such soils as the Moca, Santa Clara, or Camagüey.

Chemical analyses of these soils show that in most places they are low in plant nutrients and will be greatly benefited by the addition of manure and fertilizers. The most common fertilizer practice on these soils in the sugarcane fields is to apply 600 pounds to the acre of 12–8–5, 6 weeks after planting, and from 400 to 500 pounds of sulfate of ammonia from 6 to 8 weeks later.

Sabana Seca clay.—Sabana Seca clay has a fertile surface soil, but it is not a very productive soil because of its heavy stiff subsoil, which

resists rapid penetration of air, plant roots, and water. This soil occurs on nearly level or undulating relief from Fajardo to Camuy. It is characterized by a dark-brown medium-compact clay surface layer that plows when dry into hard dense clods but when wet slakes into fine grains much more quickly than a very plastic soil, such as Moca clay. At a depth of about 5 to 7 inches is a 3-inch subsurface layer consisting of light-yellow heavy medium-compact clay containing many rounded iron concretions. This layer abruptly changes at a depth of about 10 inches to an extremely heavy stiff plastic mottled red, rich-brown, gray, and yellow clay, which continues to a depth exceeding 30 inches. The soil material gradually becomes lighter in texture and slightly less compact. At depths below 6 feet, however, the material is distinctly mottled and medium compact.

This soil is acid in all layers and is considered by the farmers to be a poor agricultural soil. Sugarcane and grasses for pasture are the best two crops grown. Both do fairly well when the rainfall is just right, but neither returns a good yield under adverse weather conditions. Many of the low-lying areas of this soil are more productive than the average, because the subsoil frequently is wet from the high water table and plant roots can readily penetrate it.

Sabana Seca sandy clay loam.—Sabana Seca sandy clay loam is one of the most widely distributed soils. It occurs in both small and large areas from Fajardo to Isabela.

The surface layer, to a depth ranging from 5 to 12 inches, is friable brown sandy clay loam or sandy loam. It is underlain by a thin subsurface layer of light-yellow heavy clay loam containing numerous large and small irregular-shaped iron concretions, or perdigones. The subsoil, beginning at a depth between 7 and 12 inches, depending on the slope, consists of mottled red, yellowish-brown, and gray plastic stiff sandy clay. The material in this layer is so stiff and compact that it interferes with the normal development of roots and the percolation of water. The layer continues to great depths. It becomes somewhat less heavy with depth, but it is everywhere mottled and compact in place. In the semiarid sections, such as those near Isabela, the surface soil is about neutral in reaction, but in the subhumid sections the soil is acid in all layers.

Practically all of this soil is under cultivation to minor truck crops and pineapples, and these shallow-rooted crops grow fairly well if they are well fertilized. This is not a desirable soil for any plants that have a deep root system. A few fields are planted to sugarcane, but the yields are low, ranging from about 20 to 25 tons of sugarcane with irrigation and producing 15 tons without. S. C. 12/4 and Uba are the best varieties of cane for this soil. Citrus trees grow fairly well for a few years, but when the roots reach the compact layer the trees become stunted. Sweetpotatoes grow very well and produce from 1,500 to 1,700 pounds an acre. In most places the white yautia grows better than the yellow. In the vicinity of Isabela this soil is often planted to tobacco and cotton, which yield about 500 pounds and 800 pounds to the acre, respectively.

Caguas clay.—Caguas clay is similar in many respects to Sabana Seca clay. It occurs on low nearly level inner valleys in the vicinity of Caguas and on long gently sloping old alluvial fans in the vicinity of Ceiba and Lajas.

Caguas clay is characterized by a gray weakly granular acid clay surface soil about 7 inches thick, which is very plastic when wet and contains many rounded iron concretions in the lower part. This layer abruptly changes to a 10- or 14-inch subsoil of mottled yellowish-brown and reddish-brown stiff heavy dense acid clay, which gradually changes to distinctly mottled gray, deep-red, and yellowish-brown heavy stiff acid clay. Below a depth of 4 feet the soil material becomes slightly more friable and contains less clay, but it is distinctly mottled with red and gray or red and white.

As mapped, Caguas clay includes many areas, too small to show on the map, in which the surface soil has a somewhat lighter or more sandy texture. Concretionary materials are so abundant and large in some areas of this soil that they interfere with cultivation, and such areas, as those near Ceiba, are shown on the map with stone symbols.

The relief is sufficient to provide adequate external drainage during average rains, but during exceptionally heavy rains water stays on the surface for considerable time. Internal drainage is restricted, owing to the heavy subsoil. Some water flows laterally at the junction of the surface soil and subsoil. As indicated by the color of the lower part of the substratum, internal drainage is restricted even at a great depth. Only a few plant roots penetrate to a depth greater than 3 feet, but in some of the friable alluvial soils many plant roots appear below a depth of 4 feet.

About 60 percent of this soil is planted to sugarcane, and 40 percent is in pasture. Sugarcane yields from 30 to 35 tons an acre of gran cultura and about 25 tons of ratoon crops. In the vicinity of Lajas, yields are much less because of the drier climate, and most of the land is in pasture, which produces a rank dense growth of grass that is not so nutritious as the grass on some of the soils derived from soft limestone.

Caguas sandy clay loam.—Caguas sandy clay loam occurs in close association with Caguas clay on the inner valleys and old alluvial fans. The largest areas lie northeast of Naguabo and Humacao.

This soil has a 6-inch grayish-brown single-grained acid friable sandy clay loam or sandy loam surface soil that readily forms a fairly good seedbed when cultivated. It is underlain by a 10-inch compact yellowish-brown stiff subsoil that has a high content of black irregular-shaped iron concretions in the upper part. In places, the surface soil has been eroded to such an extent that the iron concretions are exposed. Such spots are of low value because the stiff nearly impermeable subsoil is almost exposed, and crops do not thrive so well as those grown on the original surface soil. Below the subsoil is the mottled red, gray, and brown compact stiff substratum, which continues to a great depth. This layer is nearly impervious to water, and in many places small basinlike areas hold water for several months at a time (fig. 122).

Almirante clay.—Almirante clay occurs in the small limestone valleys associated with soils of the Vega Alta series, from Bayamón to a point south of Quebradillas. The relief of this soil is nearly level except in and around sinkholes.

This soil is characterized by a 6- or 8-inch yellowish-brown or brown moderately friable heavy clay surface soil and a yellowish-brown, in places pinkish-brown, very heavy stiff moderately plastic subsoil that extends to a depth ranging from 24 to 30 inches. The substratum is mottled yellow, gray, and red medium-heavy clay. Limestone rock may occur below a depth of 8 feet. The acidity of the soil material increases from about pH 6.2 in the surface soil to pH 4.6 below a depth of 3 feet.

FIGURE 122.—Small basinlike areas of Caguas sandy clay loam. These basins act as reservoirs for a supply of water for livestock. Note guinea grass in the pastures and the good four-wire fence.

Pequeñas áreas en forma de cuencas en Caguas areno-arcilloso lómico. Estas cuencas sirven como represas y suplen el agua para el ganado. Nótese la yerba de guinea en los pastos y la buena cerca de cuatro alambres.

Few areas of this soil are imperfectly drained, except those affected by seepage or springs. The land is used for the production of sugarcane, tobacco, and minor crops, and it is fairly productive, although it is difficult to cultivate and is sensitive to drought, owing to the heavy texture of both the surface soil and subsoil.

In areas of this soil occurring in the vicinity of Florida are many round basinlike sinkholes which hold water for many months of the year. As this locality receives slightly more rain than most areas of this soil, crop yields are slightly higher. P. O. J. 2725 is the principal variety of sugarcane grown. It produces from 40 to 50 tons to the acre in gran cultura and about 25 tons in first ratoon. The fertilizer used on this soil in this locality is a 10–10–8 mixture.

Almirante sandy clay.—Almirante sandy clay differs but slightly from Almirante clay, but it has a lighter textured surface soil and is less difficult to cultivate.

The 6- or 8-inch surface soil consists of dull yellowish-brown or grayish-brown friable permeable sandy clay. It is underlain by a yellowish-brown, in places pinkish-brown, very heavy stiff moderately plastic subsoil extending to a depth of 30 or 33 inches. Below this layer is the characteristic mottled gray, red, and brown medium-heavy sandy clay or clay substratum, which continues to great depths before resting on the parent limestone rock. The acidity of the surface soil ranges from pH 5.5 to pH 6.0, and the soil material becomes more acid with depth.

This soil is closely associated with Almirante clay, especially in areas near Florida and southwest of Arecibo. It occupies nearly level limestone valley areas and is used for the production of sugarcane, tobacco, and minor crops, yields of which depend on the quantity of fertilizer applied and the amount of rainfall during the growing season. In some areas tobacco yields from 400 to 600 pounds an acre.

Almirante fine sandy loam.—Almirante fine sandy loam is closely associated with Almirante clay in small areas from Manatí to a point west of Arecibo. It differs from Almirante clay in that it has a much sandier surface soil and a sandier and thicker subsoil. Most of the land is used for the production of truck crops and pineapples, which grow fairly well when the land is well fertilized. The soil is not difficult to cultivate and is not affected so seriously by drought as are the other soils in this group.

Vega Alta clay, heavy-subsoil phase.—Areas of Vega Alta clay that have an usually heavy compact subsoil are classified as a heavy-subsoil phase. The subsoil is heavier, more stiff, and less easily penetrated by plant roots than the subsoil of the typical soil. This soil requires more careful cultivation than the typical soil and produces slightly lower yields of sugarcane, the principal crop grown. The same varieties are planted as those planted on the typical clay, with possibly a slightly larger proportion of S. C. 12/4. This soil occupies small areas in the limestone valleys mainly between Río Piedras and Arecibo. It has smooth or slightly undulating relief.

Vega Alta sandy clay loam, heavy-subsoil phase.—The heavy-subsoil phase of Vega Alta sandy clay loam differs from Vega Alta clay, heavy-subsoil phase, in having a sandier looser surface soil and a slightly sandier subsoil. The subsoil, however, is rather compact in places and approaches the heaviness of the Sabana Seca subsoils. This is considered a better agricultural soil (fig. 123) than the Sabana Seca soils, but not so good as the typical Vega Alta soils. Bodies occur from Carolina to a point west of Camuy. The land is used for the production of pineapples, tobacco, and cane, and yields are only fair. The sugarcane variety S. C. 12/4 yields better and has a higher content of sucrose than the other varieties that have been tried so far. A common fertilizer for this soil is about 800 pounds of 12–6–5 used in two applications.

Vega Alta clay loam, heavy-subsoil phase.—Areas of Vega Alta clay loam that have an unusually heavy compact subsoil are classified as Vega Alta clay loam, heavy-subsoil phase. This soil occurs in smooth or slightly undulating areas in the limestone valleys from Carolina to Arecibo.

Figure 123.—An estate on Vega Alta sandy clay loam, heavy-subsoil phase, and Bayamón fine sandy loam.
Finca en Vega Alta areno-arcilloso lómico, fase subsuelo pesado, y en Bayamón fino arenoso lómico.

This soil is characterized by a yellowish-brown or brown friable weakly granular clay loam or sandy clay surface soil about 7 inches thick, containing many rounded iron concretions in the lower part. This layer is underlain by light yellowish-brown heavy moderately stiff clay that gradually changes, at a depth ranging from 14 to 18 inches, to mottled yellowish-brown, reddish-brown, and gray stiff firm sandy clay or clay. This layer continues to a great depth and becomes gradually less heavy and more definitely mottled with depth.

It is not so difficult for roots to penetrate the subsoil and lower substratum of this soil as it is the corresponding layers of the Almirante soils; therefore crops grow slightly better on this soil than on the Almirante soils.

Vega Alta clay loam, poorly drained phase.—Areas of soil in the limestone valley that are imperfectly or poorly drained, owing to springs, sinkholes, or drainageways, are classified as Vega Alta clay loam, poorly drained phase. Most of these areas have a sandy clay or clay loam yellowish-brown or reddish-brown thick surface soil underlain at a depth of about 15 or 20 inches by mottled red, brown, and gray clay. In some places the subsoil is dominantly gray. In most places the water table lies at a depth ranging from 2 to 3 feet. This soil is more productive than either Vega Alta clay loam or Vega Alta clay loam, heavy-subsoil phase, when it has been drained and sugarcane is planted in the grand-bank system. The undrained land is used mostly for pasture.

Islote clay loam.—This soil occurs along the north coast within a kilometer of the sea. It is derived from sandy limestone on slightly raised sea benches. The areas parallel the coast. The surface soil is friable dark-brown or nearly black granular fairly thick clay loam containing sufficient organic matter for most plants. It is plastic enough to show vertical cracking on drying. It is underlain, at a depth of about 10 inches, by light-colored friable sandy clay grading into moderately stiff and compact brownish-red clay. Medium-sized cracks form in this layer at the extremes of moisture content. The soil material becomes more friable at a depth of about 30 inches and continues so to the parent limestone, which, in most places, occurs at a depth of about 5 feet.

This soil is used mostly for the production of sugarcane. Small areas are in tobacco and truck crops. It is a fair to good soil and is preferred to any other soil in the group. It is neutral or very slightly acid.

Islote sandy loam.—Bodies of Islote sandy loam occur along the coast at wide intervals mainly between San Juan and a point west of Isabela. The soil occupies old nearly level sea benches and is probably derived from San Juan sand dunes composed of sand cemented by lime carbonate. It is much sandier in all layers than Islote clay loam and has an abundance of black perdigón above the subsoil. It is used mostly for the production of truck crops, citrus, tobacco, and plantains, and to a very small extent for sugarcane.

Islote sandy loam, imperfectly drained phase.—Areas of Islote sandy loam that occupy low positions and have a water table within 3 feet of the surface are classified as an imperfectly drained phase of that soil. This imperfectly drained soil has a reddish-brown friable granular sandy loam surface soil underlain by a bright-red sandy clay subsoil layer, which extends to a depth ranging from 20 to 30 inches

and, in turn, rests on a mottled red, brown, and gray medium-plastic clay lower subsoil layer.

Areas of this soil occur east of San Juan and north of Carolina. The land is used mostly for the production of coconuts, truck crops, and bananas. It is very productive and is only slightly acid.

FRIABLE SOILS OF THE COASTAL PLAINS

The friable soils of the coastal plains include the heavier textured soils of the Bayamón, Coto, Espinosa, Matanzas, and Vega Alta series. These soils are derived from medium-hard limestone and occur in flat or gently rolling valleys that have been formed by the solution and erosion of large sections of the limestone. They occur throughout the north coast limestone belt from Aguadilla east to Carolina, and they range in elevation from 100 to 600 feet above sea level. They are heavy textured, permeable, and neutral or acid soils. They have a number of important characteristics peculiar to certain tropical soils. They have similar physical and chemical properties from the surface to the underlying limestone rock. They have a high percentage of clay-sized particles, grouped more or less in clusters, causing the physical characteristics of the soils to be more like loams or sandy loams than clays. When wet, these soils are somewhat sticky and slippery but not nearly so much so as other soils having the same content of clay. They dry very quickly, and cultivation is seldom delayed very long after a rain. Even if these soils are worked when wet and large clods are turned up, the soil material soon slakes to small crumblike particles after the first or second rain. These clay soils do not swell or crack greatly at the extremes of moisture content. Regardless of moisture conditions, water freely penetrates all except the Vega Alta soils, thus showing a decidedly porous character. Evidently the capillary pores are not clogged by the very slight expansion of the soil on wetting but are open continuously. Although water penetrates these soils very rapidly, it is not retained so well as it is in other clay soils, and during dry spells these soils dry to great depths. Owing to the porous character of the soils, evaporation is excessive, and frequent rains or irrigations are necessary for good crop production. Because of the rapid percolation, many plant nutrients and fertilizers are washed into the lower part of the subsoil, out of reach of plant roots. These soils are therefore not highly productive, even though they have very good tilth and a thick subsoil.

The Coto soils are recognized by their yellowish-brown friable clay subsoils and the Matanzas soils by their bright-red subsoils. The Espinosa and Bayamón soils are acid counterparts of the Coto and Matanzas soils. The Espinosa and Bayamón soils occur mainly from Río Piedras to Arecibo, where the average annual rainfall is above 60 inches, whereas the Coto and Matanzas soils occur mainly from Arecibo to Aguadilla where the rainfall is less than 60 inches. Most of the Vega Alta soils occur in places where the rainfall is greater than 65 inches, and they are very acid, heavily leached, light-colored soils with more mottled subsoils and less perfect drainage than the other soils in the group.

A very noticeable feature of the areas in which these soils occur is the lack of streams or drainageways. All surplus water drains into sinks and sinklike depressions, some of which hold water. The latter are

especially numerous near Florida. The water from these depressions is used both for people and for livestock, but in most places the supply of water is not sufficient to last throughout the dry season.

Many thousands of people make their living from these soils, and throughout the area near Florida there are many houses. The farms are small, except in areas owned by sugar centrals.

Erosion is negligible on these soils because of their nearly level surface and permeable surface soils and subsoils. There is some erosion near the sinkholes, however, as the rims of the holes have much shallower surface soils than the surrounding areas. Near the bottoms of the sinks the soil is dark to considerable depth, indicating deposition.

Chemical analyses, as well as experiments in fertilization, show that all these soils are low in plant nutrients, yet nearly 100 percent of their area is cultivated. Sugarcane is the leading crop. Yields vary greatly, according to climatic conditions and crop management, but in general these soils have never been very productive for sugarcane. They occur over a rather wide range in annual rainfall, which is reflected in crop yields. Unless irrigated, these soils in areas receiving less than 65 inches of annual rainfall (as shown in fig. 34) are much less productive than the areas having a higher rainfall. Yields of more than 50 tons of sugarcane an acre are very uncommon, whereas on alluvial soils or some of the soils on terraces yields of 60 tons are common. In most of the areas irrigation will cause an increase of 10 to 15 tons an acre in yields of sugarcane. The best varieties grown are P. O. J. 2725 and P. O. J. 2878. Mayagüez 28, P. R. 809, and F. C. 916 are proving very promising where they have been tried. S. C. 12/4 produces well but is not desirable because it is susceptible to mosaic. The fertilizers used at present are 12–6–5 and 10–10–8, generally about 800 pounds to the acre for the first application and 200 pounds of sulfate of ammonia 100 days later. So far fertilization experiments [24] on Coto clay show that about the best fertilizers are the following, in acre applications: 100 pounds of ammonia, 30 pounds of phosphoric acid, and 120 pounds of potash; or 100 pounds of ammonia, 60 pounds of phosphoric acid, and 60 pounds of potash. This soil is representative of this subgroup of soils.

Wrapping tobacco grows very well on these soils and is the second largest crop. The main variety is Virginia Blanca, and it yields about 600 pounds an acre. Pineapples grow very well on the Espinosa, Vega Alta, and Bayamón soils, but the Matanzas and Coto soils are slightly too alkaline for good production of pineapples. Red Spanish is the main variety grown. It yields from 200 to 250 crates an acre for the first crop, about 150 or 200 crates the first ratoon, and about 100 crates the second ratoon. Grapefruit trees grow fairly well, but not nearly so well as on the sandier textured soils of the several series. Other crops successfully grown are oranges, plantains, sweetpotatoes, ñames, peppers, cucumbers, and yuca.

Superficially these soils appear to have a large content of sand, because the sand grains that are present are very conspicuous. Actually the percentage of sand is relatively low, especially in the heavier types and in the subsoils. When a dry clod is crushed between the fingers it breaks easily into many small aggregates that look very much like sand, but on wetting they break to smooth friable mate-

[24] Experimental work by L. A. Serrano, director of the Isabela experiment substation.

rial, indicating that most of the material is clay. The mechanical analyses of these soils confirm this observation, as they show that from 60 to 95 percent of the surface soil is clay, and the remaining 40 to 5 percent is about equally divided between medium sand, fine sand, very fine sand, and silt.

The method used at present to differentiate the various soil classes is based on the proportions of the different-sized particles in the surface layers. Under the present system of analysis, all soils containing more than 50 percent of particles less than clay-sized units, 0.005 millimeters in diameter, are called clay. Therefore, the soils with 90 percent or more of clay would be classified as clay just as are those having less than 60 percent of clay. The Coto soils containing about 60 percent of clay in the surface soil work much more easily and are planted to more different kinds of crops than are the Coto soils having 90 percent of clay. It is realized that for these particular lateritic soils, another system of differentiating the clay soil class must be used. Therefore, in this area, for this soil, the clay class has been subdivided into two parts, namely, Coto clay, heavy phase, for areas having about 90 percent of clay in the surface soil, and Coto clay for areas having about 75 percent.

Coto clay, heavy phase.—Coto clay, heavy phase, is the most extensively cultivated soil of this series. It occurs on slightly rolling or undulating areas in the northwestern part of the island, especially in the vicinity of Isabela. A characteristic feature of this soil, as well as of Coto clay, is the presence of numerous rounded sinks having gently sloping sides and ranging from 10 to 15 feet in depth. In most places, by contour farming, the sinks are planted to sugarcane and some areas are irrigated. The soils are practically the same as the surrounding level land, and only during very heavy rains are crops in the sinks damaged. Small areas of limestone outcrops are common on this soil, especially in the northwestern part of the island.

This soil is characterized by a dark grayish-brown permeable slightly plastic clay surface soil about a foot thick, underlain by a reddish-brown slightly compact permeable clay subsoil and, in turn, by a yellowish-brown nonplastic clay substratum, which in most places rests on hard limestone at a depth of about 6 feet, although the depth may vary from 26 inches to 12 feet. This soil is slightly acid, having a pH value of 6.0 to pH 6.5 in all layers. Most of the soil near Isabela is under irrigation, and most of the irrigable land under the ditch is being irrigated at present.

Probably more than 70 percent of this soil is planted to sugarcane. This high percentage shows that the soil is better adapted to sugarcane than to any crop yet tried. The best suited sugarcane varieties seem to be P. O. J. 2878 and P. O. J. 2725. Yields range from 25 to 50 tons an acre with irrigation and fertilizer. A considerable quantity of ñames are grown, especially in the northern part of Barrio Ceiba Baja. Ñames yield about 6,000 pounds an acre on nonirrigated land and from 8,500 to 10,000 pounds on irrigated land. Yautias also do well. A few large fields have been planted to coffee, but are yielding only about 150 pounds to the acre. Other crops commonly grown in small acreages are corn, pigeonpeas, and beans. A few citrus trees have been planted, but indications are that this soil is slightly too heavy for very good yields from citrus.

Coto clay.—Coto clay occurs in nearly level areas, the largest of which are southwest of Isabela and south of Quebradillas. This soil is very similar to Coto clay, heavy phase, but the surface soil is slightly more friable, looser, and has a higher sand content.

Most of the irrigated areas are planted to sugarcane, which so far has proved to be the most profitable crop adapted to this soil. Yields are slightly less than on Coto clay, heavy phase. Some fields, however, have produced 50 tons of gran cultura sugarcane to the acre under irrigation. It is seldom profitable to have more than two ratoons on this soil. Experiments with the cane varieties P. R. 809 and P. O. J. 2878 seem very favorable for this soil. Other crops returning a good profit when the land is irrigated are Red Spanish peppers, which yield about 150 crates to the acre; tomatoes, about 200 crates; tobacco, from 600 to 800 pounds; and corn, from 1,000 to 1,500 pounds. Corn yields probably can be increased to a very great extent by planting improved varieties. Ñames also are profitable, and they yield 10,000 pounds an acre in very favorable years. Some farmers have more than one crop on their land at the same time; for instance, young cotton, beans, and 18-inch or 2-foot banana trees. In nonirrigated areas, tobacco and minor crops are the principal crops grown.

Coto sandy clay.—Most areas of Coto sandy clay lie nearer the coast than do those of Coto clay, but the two soils are closely associated. The relief is the same as that of Coto clay, and the profile is nearly the same. The surface soil, however, is slightly more sandy and more friable than that of the clay. This soil is better adapted to a larger variety of crops than any other soil of the Coto series. It is not a high-yielding soil, and it requires frequent rains or irrigation and much fertilizer. The following are average acre yields on this soil when irrigated: Sugarcane, 20 to 40 tons; corn, 1,500 pounds; and sweetpotatoes, 2,000 pounds. Even in high-rainfall areas, the yields on nonirrigated land are about one-third less than those on irrigated land.

Espinosa clay.—Espinosa clay is characterized by a 6- to 10-inch surface layer of light-brown highly granular soil, a 25-inch light yellowish-brown or reddish-yellow somewhat stiff and finely cloddy clay upper subsoil layer, and a 15- to 30-inch reddish-yellow friable clay lower subsoil layer, which, in some places, is mottled red and yellowish brown in the lower part. Limestone, the original parent material, occurs at greatly varying depths. The entire profile is moderately or strongly acid, except where the soil has received applications of lime.

This soil occurs throughout the limestone belt east of Río Guajataca. It has a heavier surface soil and a slightly more heavy subsoil than has Coto clay. It is more difficult to cultivate, but, owing to its occurrence in sections where the rainfall is higher, it averages somewhat more productive than Coto sandy clay. Most of the land could be improved greatly by plowing under leguminous cover crops. It is used almost entirely for the production of P. O. J. 2725 sugarcane, which yields from 30 to 40 tons gran cultura and about 20 or 30 tons ratoon. Very little primavera cane is planted.

Espinosa sandy clay.—Espinosa sandy clay, the most extensive soil of the Espinosa series, is very similar to Coto sandy clay except that it is more acid and has a red subsoil. It occupies numerous very

well drained gently undulating areas east of Río Guajataca. Sugarcane yields less than on Espinosa clay, but pineapples yield slightly better.

Matanzas clay.—Matanzas clay is the most important soil of the Matanzas series. It occurs throughout the same general areas as does Coto clay, heavy phase, but most of it is adjacent to the limestone hills. It has a friable brownish-red permeable softly granular clay surface soil underlain by a deep-red slightly plastic but permeable clay subsoil. In most places limestone is present at a depth ranging from 6 to 10 feet. The acidity of this soil ranges from pH 6.2 to pH 6.8 in all layers. Little change is noted in the profile below the topmost 8 or 10 inches. The material in all layers contains more than 90 percent of clay, but roots penetrate easily, and they are not deformed as they are in the heavy plastic Sabana Seca and similar soils having stiff compact subsoils.

This soil is slightly more productive than Coto clay. About 70 percent of the land is in sugarcane, which produces about 40 tons gran cultura cane to the acre, provided the rainfall exceeds 60 inches. When irrigated this soil may produce 50 tons gran cultura and about 30 tons ratoon. The fertilizer used by many growers on this soil is 400 pounds to the acre of 10–10–8 or 12–6–5 as a first application and 400 pounds of sulfate of ammonia as a second application about 2 months later. Sugarcane is planted in furrows, generally with the contour, especially in the irrigated districts. The best sugarcane varieties now grown are Mayagüez 28 and P. O. J. 2878, in which the sucrose content is high. With these canes three or four ratoons are produced. Other crops produced on this soil and their average acre yields are as follows: Sweetpotatoes 1,500 pounds, pigeonpeas 500 pounds, beans 150 pounds, yuca 2,500 pounds, and yautia 2,000 pounds.

Matanzas sandy clay.—Matanzas sandy clay is much less extensive than Matanzas clay. It occurs in spots here and there throughout the limestone areas west of Río Manatí. It differs from Matanzas clay in that it has a lower percentage of clay in the surface soil and is more productive. It is easier to cultivate and is a more desirable soil than the clay type. Nearly the entire area under irrigation is cultivated to sugarcane. The land produces fair citrus. In nonirrigated areas subsistence crops grow around the small houses that dot the landscape.

Bayamón clay.—Bayamón clay has characteristics similar to those of Matanzas clay, but it is more acid in all layers. Areas occur from San Juan west to Camuy, but more of them lie east of Vega Alta. This is a more desirable soil for the production of pineapples than are the Matanzas soils, but it is less productive for sugarcane.

Bayamón sandy clay.—Bayamón sandy clay is developed principally in large valleys extending from Vega Alta to a point west of Arecibo. It resembles Bayamón clay, but it contains less clay in the surface soil. Probably about 80 percent of the land is used for the production of sugarcane, and the other 20 percent is planted to pineapples, citrus, and tobacco. Yields of almost all crops range from fair to good.

Bayamón sandy clay loam.—Bayamón sandy clay loam is one of the less important agricultural soils along the north coast. It differs from Matanzas clay in that it is strongly acid in all layers. It occurs

in small areas mainly between Arecibo and Manatí. All the land is under cultivation to sugarcane, tobacco, and minor truck crops, and yields are slightly larger than those obtained on Bayamón clay.

Vega Alta clay.—Vega Alta clay is a highly leached soil occurring in undulating areas in the larger valleys and in small valleys from Manatí to a point near Arecibo. It has a friable brown or light brownish-gray heavy clay surface soil about 8 inches thick, underlain by a reddish-brown heavy slightly plastic clay layer about 10 or 12 inches thick. This layer rests on more compact mottled brown, red, and gray clay, which continues to great depths before limestone is reached. This mottled subsoil layer is less permeable than the subsoils of the other soils in this group, and it interferes somewhat with rapid percolation of water. It is noticed that in the areas near Bayamón, where the rainfall is greatest, the mottled layer is much nearer the surface than in the areas west of Arecibo. Yields are about the same as those obtained on Espinosa clay.

Vega Alta clay loam.—Vega Alta clay loam resembles Vega Alta clay, with which it is closely associated, but it has a lower clay content. It is more easily cultivated and produces slightly more than the clay type, but in other respects the two soils are nearly the same. The clay loam is more extensive than the clay, as it occurs from San Juan to a point near Quebradillas.

Some of the crops produced on this soil and the average acre yields are as follows: Sugarcane 40 tons, yautia 2,000 pounds, ñames 3,500 pounds, yuca 1,500 pounds, sweetpotatoes 2,000 pounds, beans 300 pounds, corn 1,000 pounds, tobacco 600 pounds, pigeonpeas 300 pounds, and beans 400 pounds.

Vega Alta sandy clay loam.—Vega Alta sandy clay loam differs from Vega Alta clay in that it is more friable, sandier, and easier to cultivate. It is a less desirable soil for the production of sugarcane but more desirable for grapefruit and pineapples. It occurs throughout the area from Vega Alta to a point near Arecibo. East of Florida are areas that are producing from fair to good yields of pineapples and grapefruit. Everbearing strawberries grow fairly well. Strawberries are scarce in Puerto Rico and sell for a high price, but there is little demand for this crop.

VERY FRIABLE SOILS OF THE COASTAL PLAINS

The soils of the coastal plains with very friable subsoils include the best soils in Puerto Rico for the production of grapefruit. They are the sandy-textured types of the Vega Alta, Espinosa, Coto, Bayamón, Maleza, Islote, and Río Lajas series, and all are derived from limestone. The Vega Alta, Espinosa, Bayamón, and Río Lajas soils occur in subhumid or humid sections and therefore are acid and leached. The Vega Alta soils are more leached than the other soils. The Coto, Maleza, and Islote occur in subhumid and semiarid sections and therefore are less acid and less seriously leached than the soils of the other series.

The soils of this group have nearly the same characteristics as the heavy-textured soils of their respective series, but they have looser, more friable, lighter textured, and thicker surface soils and slightly more friable and less heavy subsoils. Because these soils are more permeable, looser, and more sandy, they are better adapted to grape-

fruit and truck crops than are the heavier textured soils, but they are not so well adapted to sugarcane. The grapefruit trees growing on these sandy soils bloom early and heavily, and, with irrigation, the fruit is large. The three main crops grown on the soils of these seven series are sugarcane, grapefruit, and tobacco. Acre yields of sugarcane range from 10 to 15 tons on the loamy sands, from 15 to 20 tons on the sandy loams, and from 35 to 50 tons on the heavy-textured soils. Vigorous prime grapefruit trees under good management yield from 15 to 20 boxes to the tree on the loamy sands, from 8 to 15 boxes on the sandy loams, and from 3 to 8 boxes on the heavy-textured soils. A 6-year-old tree will produce about twice as much as a 3-year-old tree. Tobacco yields about 300 pounds to the acre on the loamy sands, 500 pounds on the sandy loams, and about 600 pounds on the heavier soils.

In grapefruit groves that have loamy sand, sandy loam, and clay soils adjoining, it is noticed that the trees are about two or three times as large on the loamy sand as on the clay soil of the same series. The trees on the sandy loam are about as good as the smaller trees on the loamy sand of the same series. In one well-managed 17-year-old grapefruit orchard, the branches of the trees growing on the loamy sand had completely filled in all the available space, whereas those growing on the clay were only about one-third as large and the spaces only about one-half filled in, and other citrus trees were being planted in order to fill in the spaces between the trees and keep down the weeds. This great difference in tree growth is not so apparent in the first few years or in later years if irrigation has been practiced the entire time or if the average annual rainfall is over 80 inches.

A common fertilizer used in the citrus orchards is 30 or 35 pounds of 6–8–10 a tree for trees producing about 20 boxes of fruit and from 15 to 20 pounds for trees producing about 10 boxes a tree.

A noticeable characteristic of the sandy loams and to less extent of the loamy sands of all these soils is a large quantity of iron concretions, or perdigones, in the lower part of the surface layer. If, through erosion or some other cause, the surface layer becomes so thin that many perdigones occur on the surface, the value of the soil is greatly reduced. It is thought that the perdigones have little effect on the crops, but, because of the shallow surface soil and the nearness to the surface of the heavy subsoil, crop yields are reduced. All these soils are low in fertility, as are most sandy soils.

Vega Alta fine sandy loam.—Vega Alta fine sandy loam is a fairly extensive friable brown soil occurring in the limestone valley sections from Carolina to a point near Quebradillas. In cultivated fields the 10- to 14-inch surface soil is yellowish-brown loose friable fine sandy loam, which is abruptly underlain by a yellowish-brown or faintly reddish brown firm medium-compact sandy clay subsoil that does not allow water to percolate through it so readily as does the corresponding layer in the soils of the other series in this subgroup. At a depth ranging from 24 to 34 inches is mottled red, yellowish-brown, and gray friable clay, which continues to a great depth and becomes slightly less heavy with depth. This is the least productive sandy loam soil in this subgroup. Most of the land is in tobacco, grapefruit, and sugarcane, ranking in acreage in the order named.

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Vega Alta loamy fine sand.—Vega Alta loamy fine sand occurs from Carolina to a point south of Quebradillas. It differs from Vega Alta fine sandy loam in having a thicker and more sandy surface soil. The loamy fine sand surface soil in most places continues to a depth of more than 20 inches before the heavy sandy clay or clay subsoil is reached. This thick surface soil allows better and quicker root development. Therefore, grapefruit trees are more productive than those on Vega Alta fine sandy loam. The reverse is true with sugarcane. During hurricanes, grapefruit trees are more apt to be blown over on the loamy fine sands than on the heavier soils, but they are replanted or pulled back into place more easily.

Espinosa sandy loam.—In some respects Espinosa sandy loam is the most desirable soil of the Espinosa series. The sandy surface soil is easily cultivated. The rain water sinks through it very rapidly but is more readily available to plant roots than in the heavier textured soils. This soil has a noticeably less heavy texture than has Espinosa sandy clay, the soil it most nearly resembles. It has a 10- or 12-inch surface soil of light grayish-brown sandy loam underlain by a heavier more compact reddish-brown subsoil. At a depth ranging from 36 to 40 inches is the mottled gray, yellowish-brown, and red sandy clay substratum. This soil occurs from San Juan to a point west of Camuy. It is more acid than the heavier textured Espinosa soils. It produces good yields of truck crops and tobacco, and grapefruit does fairly well, in fact, much better than on the heavier textured soils.

Espinosa loamy sand.—Espinosa loamy sand differs from Espinosa sandy loam in that it has a much thicker and slightly more sandy surface soil. The light-brown or yellowish-brown sandy loam or loamy sand surface soil extends to a depth ranging from 15 to 20 inches before the heavier subsoil is reached. The subsoil is very similar to that of Espinosa sandy loam. This soil is best adapted to grapefruit, truck crops, coconuts, and pasture, ranking in suitability in the order named. Grapefruit does much better on this soil than on the heavier textured soils. Minor crops also do very well; however, the mole cricket, or changa, often does considerable damage to young tender plants.

Coto loamy sand.—In physical characteristics, Coto loamy sand is nearly identical with Espinosa loamy sand, but chemically it is more alkaline and for that reason has been classified in the Coto series. It produces about the same crops with the same yields as does Espinosa loamy sand. It is associated with Coto sandy clay from Manatí to Arecibo.

Bayamón fine sandy loam.—Bayamón fine sandy loam is easily recognized by its deep-red color. It occurs in areas where the average annual rainfall is more than 60 inches. It is characterized by a brownish-red loose acid friable fine sandy loam surface soil about 12 inches thick. This layer is underlain by a purplish-red heavier acid sandy clay subsoil that becomes lighter in texture and more friable at a depth of about 2 feet. This layer, in turn, continues downward to limestone which in places lies at a depth of more than 20 feet. Farmers consider this soil well adapted to grapefruit and truck crops, but it is not a highly productive soil for sugarcane.

Bayamón loamy fine sand.—Bayamón loamy fine sand differs from Bayamón sandy loam in that it has a much thicker and sandier surface

soil. It is considered the best soil for citrus on the north coast. It requires large quantities of fertilizer and some irrigation for best production.

Maleza fine sandy loam.—The areas of Maleza fine sandy loam are level or nearly level. This soil occurs chiefly in the northwestern part of the island where the climate is subhumid to semiarid, and, therefore, it has not been leached of its lime and bases to so great an extent as has the more acid but very similar Bayamón loamy fine sand, the soil it most closely resembles. The Maleza soil has an 8-inch surface layer of loose friable noncoherent reddish-brown sandy loam, the lower part of which is slightly heavier than the topmost inch or two. Below this layer is a slightly compact red neutral sandy clay layer that extends to a depth of about 2 feet, below which depth the material gradually becomes somewhat more friable. The acidity of this soil ranges from pH 6.5 to pH 7.2. In places, especially in the western part of the area in which this soil occurs, the compact subsoil layer is very bright red and is very compact when dry. In places it is compact to a depth below 4 feet. The compactness of this layer is caused by the cementing action of the fine clay particles mixed with the numerous sand grains. When the material in this layer becomes dry it is very hard and compact, and it would be difficult for roots to penetrate; but when wet it becomes mellow and roots penetrate it easily.

This soil under irrigation produces fair yields of sugarcane, plantains, and bananas. Sugarcane yields from 25 to 35 tons to the acre, and plantains yield from 300 to 400 fruits an acre every 15 days. The fertilizer commonly used for plantains is a 10–7–7 mixture. When irrigated, this soil is easily managed, as the subsoil is soft as long as it is wet and the surface layer is always easily handled. Near Isabela this soil requires frequent irrigations, and it is nearly unproductive without irrigation, except for such plants as "straw-hat" palms and coconuts. Under irrigation this soil should be very productive for vegetables and citrus fruits.

Maleza loamy sand.—Maleza loamy sand is looser and more friable in all layers than Maleza fine sandy loam. In most areas the surface soil ranges in thickness from about 14 to 18 inches. It consists of brownish-red loamy sand or loamy fine sand, which is very porous and only slightly acid. The subsoil also is less red and less heavy than the corresponding layer of Maleza fine sandy loam. This soil produces fair yields of sweetpotatoes, beans, and corn without irrigation, but it produces much better with irrigation. Good yields of plantains are obtained. Generally from 200 to 250 fruits are gathered every 2 weeks from an acre of healthy bearing plants. This soil should be very productive for vegetables or citrus under irrigation. It should be equally as good as the best soil for citrus on the island. Plant roots can penetrate the subsoil layer regardless of whether or not the soil is wet or dry. Almost all sandy soils are deficient in nitrogen and phosphorus, and this soil is no exception; therefore the fertilizers used should contain rather large quantities of these elements.

This soil requires considerable attention in irrigation, especially as regards the flow of water from the laterals to the plants. The furrow must be wide and rather deep, and the flow must be fast enough to spread over a considerable area in a short time, in order to eliminate the trouble experienced when the small furrows fill with sand or the

banks cave, but the spread of the water should not be such as to cause deep furrows to be cut in the land.

Areas of this soil are associated with areas of Maleza fine sandy loam. In several areas small jagged limestone rocks protrude above the ground, thereby reducing the value of the land. The rocky areas are shown on the soil map with rock-outcrop symbols.

Islote loamy sand.—Islote loamy sand is decidedly red or purple throughout all layers and very easily could be mistaken for either Bayamón loamy fine sand or Maleza loamy sand. It is derived from a calcareous sandstone that fringes the northern coast line. On close examination it will be noticed that it has slightly different physical and chemical characteristics from those of either the Bayamón or Maleza soils. In a cultivated field it has a dark purplish-brown, loose, friable, neutral surface soil about 12 inches thick that in most places has very good tilth. The subsoil is purplish-red or reddish-purple sandy clay loam that is heavier than the surface soil and is slightly plastic—more so than the subsoils of either the Bayamón or Maleza soils. The subsoil grades into light-red or, in some places, reddish-yellow sandy loam that rests on sandy limestone at a depth generally below 5 feet. This soil is more alkaline than Maleza fine sandy loam. It is used mostly for pasture and truck crops. Lettuce does exceptionally well.

Islote sand.—Islote sand is very similar to Islote loamy sand, but it is much more sandy in all layers. The largest areas are west of Arecibo. It has slightly more undulating relief than Islote loamy sand, but this feature does not interfere with cultivation. It is not so desirable a soil as either Islote loamy sand or Maleza loamy sand. It is used mostly for guinea-grass pasture and coconuts.

Río Lajas sand.—Río Lajas sand occupies positions similar to those occupied by Islote sand and in many places is closely associated with that soil. The surface soil consists of a 10- to 15-inch grayish-brown, noncoherent, friable, acid sand, which is underlain by a deep-brown or yellowish-brown strongly acid sand or loamy sand subsoil. This soil is developed over Tertiary limestone, but a part of the material is wind-blown from the disintegrating limy sandstone along the coast.

This soil is very friable and excessively drained and therefore is better adapted to guinea grass and coconuts than to most of the other crops commonly grown. Fertilizer is seldom used for these crops, and yields are not very high.

Río Lajas sand occurs in only a few areas. The most important ones are near Arecibo and east of Santurce.

Río Lajas sand, hardpan phase.—A few small areas of Río Lajas sand have a cemented iron hardpan at a depth ranging from 2 to 3 feet, and these areas are mapped as Río Lajas sand, hardpan phase. The surface soil has been leached of most of its iron, which has precipitated in the subsoil. This soil is similar in all other respects to the typical soil, and it is just as productive for the crops commonly grown.

LOOSE SOILS OF THE COASTAL PLAINS

The loose soils of the coastal plains include soils of the Guayabo, Corozo, Algarrobo, and St. Lucie series. These soils are distinguished readily from any soils heretofore described, in that they have either light grayish-brown, nearly white, or nearly black, very loose, noncohesive, sandy surface soils and medium-heavy stiff mottled red,

brown, and gray sandy clay subsoils that in some soils lie at a depth of more than 4 feet from the surface. They occur on the coastal plain and have level to rolling relief. Most of them are not more than 2 miles from the seashore. Although very sandy, they are not exceptionally well drained, except the deeper areas. The water percolates very readily through the surface soil, but the heavy more or less impermeable subsoil retards the downward movement of water, and it runs laterally along the top of the heavy subsoil.

These soils contain only a small quantity of plant nutrients, primarily because the natural inherent productivity is low, owing to the coarse texture of the soils; and secondly, because most of the soluble plant nutrients have been leached out, owing to a combination of high rainfall and porous soil. Fertilizer is readily leached, and therefore barnyard manure is preferable as a soil amendment. Leguminous crops, such as crotalaria and cowpeas, are very good as green-manure crops, but even their effect is of short duration. The better grades of these soils are utilized mainly for truck crops, and cotton is grown in some areas. The better areas are easy to cultivate and respond to applications of fertilizer or manure, but the poorer more acid soils are either in pasture or are merely wasteland. Sugarcane generally is a complete failure on these soils. The mole cricket, or changa, is very destructive to crops planted on these loose, noncoherent, sandy soils. It is extremely difficult to irrigate the soils, and they require almost prohibitive quantities of water. Guayabo fine sand, shallow phase, requires the least water.

Guayabo fine sand.—Guayabo fine sand is characterized by a deep layer of grayish-brown fine sand overlying a mottled compact stiff subsoil. It occurs in undulating or rolling areas in the vicinity of Isabela.

In a cultivated field the surface soil consists of grayish-brown loose noncoherent single-grained fine sand about 14 inches thick. This layer is low in organic matter, and it is about neutral in reaction. Below this layer and continuing to a depth ranging from 3 to 4 feet is gray loose sand. This material rests on mottled gray, red, brown, and reddish-brown compact medium stiff sandy clay, which continues to a depth of many feet with little change.

Owing to the single-grain structure of the sandy surface soil, combined with its occurrence in knoll-like positions in a section characterized by strong northeastern trade winds, this soil is subject to blowing and shifts somewhat with the wind where not protected by vegetation. This soil is droughty, but it responds quickly to small amounts of precipitation. Owing to its physical characteristics, it is better adapted to cotton, elephant grass, guinea grass, and minor crops, such as melons and sweetpotatoes, than to other crops. Cotton, including the seed, yields from 300 to 400 pounds to the acre. The planted grasses are sometimes pastured and at other times are cut and fed to the cattle. For either purpose, about 2 acres are required to provide sufficient feed for an animal during the year.

This soil is within the Isabela irrigation project, but it is either so sandy that very few areas are irrigated, or it requires the use of prohibitive quantities of water so that the results would not warrant the expense. If irrigated, the laterals would require careful watching, in order to prevent the water from forming gullies in the land or from causing the laterals to fill with sand.

Mole crickets are very destructive and numerous in this soil. A few groves of coconuts are producing very well, and the coconut industry would increase were it not for the rick of losing the trees during hurricanes.

Guayabo fine sand, shallow phase.—The shallow phase of Guayabo fine sand occurs in undulating or level areas of the coastal plains west of Río de la Plata. A few areas are near Boquerón.

This soil consists of a single-grained loose friable grayish-brown fine sand surface layer about 16 inches thick, which is underlain by a mottled red, yellowish-brown, and gray plastic medium-stiff clay layer many feet thick. This layer expands and contracts greatly at extremes of moisture content, and, therefore, wide cracks occur when the soil is dry. The acidity of the soil material ranges from pH 6.5 to pH 6.8 in the surface soil and from pH 6.0 to pH 6.2 in the subsoil.

Owing to the sandy loose character of the surface soil, areas of this soil in the irrigated districts are not watered to a very great extent, as the soil requires large quantities of water and careful attention during irrigation to keep the soil from washing and the laterals from either filling with sand in level areas or forming gullies on steep slopes.

This soil is best adapted to melons, vegetables, pasture, and cotton. It is a very poor soil for sugarcane. Some areas in the western end of the island are in coconuts, which grow fairly well, and some are in Japanese or Uba sugarcane, but the content of sucrose is very low. Most varieties of sugarcane produce about 15 tons an acre. Ordinarily cotton yields from 400 to 600 pounds of seed cotton to the acre, but when the land is irrigated and fertilized with 800 pounds of 14–6–5, from 800 to 900 pounds of cotton is obtained. The main pasture grasses are guinea grass and elephant grass, both of which grow very well. About 1 acre is required to keep an animal throughout the year. This soil is very slightly acid in the surface soil and medium acid in the subsoil.

Corozo fine sand.—One of the most infertile level soils of the coastal plains is Corozo fine sand. It occurs mainly along the northern coast in sections where the average annual rainfall exceeds 60 inches. It occupies several square miles but agriculturally is not important, as probably less than 20 percent is farmed and the other 80 percent is idle land, on which grow icacos, avocados, cashew nuts, corozo palms, and a few coconuts. The land in general is either barren or only sparsely covered with vegetation.

In undisturbed areas this soil has a 2- or 3-inch dark-gray fine sand or sand surface layer. The 15- to 20-inch subsurface soil consists of noncoherent fine sand or sand. The upper part is much darker than the nearly white lower part. This layer changes abruptly either to a dark-brown, black, or reddish-brown cemented sandy organic layer 2 or 3 inches thick or a gray compact stiff sandy clay layer containing some yellowish-brown streaks and red splotches, 4 or 5 inches thick. Below this material is mottled gray, light-gray, and yellowish-brown sandy clay which is exceedingly compact in place but readily crushes between the fingers to fine grains. This layer continues to a great depth. At one place it may be observed below a depth of 30 feet.

All layers have a reaction below pH 4.0, which is exceedingly acid. This soil appears to be well drained, but after heavy rains water remains on the cemented organic hardpan layer for considerable time,

and the pore space in the surface soil may fill, causing water to stand on the surface. Owing to slow percolation through the organic hardpan layer, water flows laterally just above this layer and eventually reaches a drainageway. Throughout areas of this soil are many small man-made basins to catch and hold water for household use as well as for livestock. The holes are dug about 2 feet below the hardpan layer, and water falling or draining into them remains for a long time, unless used.

This soil is very infertile and very droughty, but pineapples grow fairly well when the land is heavily fertilized and properly drained. The first crop on a well-managed field may produce 150 crates to the acre, but the ratoon crops are much less. Grapefruit trees growing on this soil produce about one-fourth of a box on an average-sized tree and about one box each on the best trees. Sweetpotatoes yield fairly well. Guinea grass and elephant grass will grow, but from 3 to 4 acres of pasture are required to maintain an animal. It is doubtful whether the grass produced from these soils is as nutritious as that produced from more alkaline soils having a much higher content of plant nutrients.

Algarrobo fine sand.—Algarrobo fine sand differs from Corozo fine sand in that it has a black or black and white surface soil which in few places is more than 13 inches thick above the black or reddish-brown organic hardpan layer. The lower part of the subsoil and the substratum of these two soils are nearly identical in both physical and chemical characteristics. The material in all layers is very acid. This soil is not so well drained as is Corozo fine sand, and in many places drainage ditches are necessary to lead away the surplus water so that it does not remain on the surface of the ground. The organic matter is higher in the topmost foot of Algarrobo fine sand than in the corresponding layer of Corozo fine sand. Therefore, if this soil is properly drained, truck crops produce fairly well in favorable years. Liming and fertilizing of the land are prerequisites for favorable crop returns. It would, however, probably require prohibitive quantities of such amendments to insure a lasting effect, as leaching proceeds rapidly in this soil.

St. Lucie fine sand.—St. Lucie fine sand, which occurs in Florida, also occurs along the north coast of Puerto Rico. It is very readily recognized by the nearly white surface soil and the dunelike relief. This soil has a white or light-gray loose friable noncoherent strongly acid sand or fine sand surface soil that changes but little in color, texture, structure, or consistence to a depth below 4 feet—in places below a depth of 12 feet. In some places, however, at a considerable depth, the same material occurs under this soil as under Corozo fine sand. The organic hardpan layer may be rather faintly developed in places, but the compact stiff mottled gray and grayish-brown sandy clay material is present everywhere.

This soil is excessively drained, and frequent rains are necessary for fair plant growth. A light rain is more beneficial, however, to the plants growing in this soil than to those growing in a heavy clay soil. This soil shifts somewhat with the winds and is considered a very poor agricultural soil. It is less valuable than Corozo fine sand. Most of it is idle or is growing up to brush and weeds, neither of which forms a very dense growth. Icaco, coconuts, sweetpotatoes, and cashew nuts grow better than do most other crops.

SOILS OF THE RIVER FLOOD PLAINS

The soils of the river flood plains include all the recent alluvial soils, which are the most suitable soils for the production of sugarcane. Therefore, under present conditions they are the most valuable. Some of the best grapefruit orchards and the best pineapple fincas have a higher acre value than the average alluvial land, but the price includes both land and crop. The soils of the river flood plains are excellent agricultural soils, and they are intensively farmed to sugarcane year after year and continuously throughout the year. More than 90 percent of the soils in this group are used for this crop. Most of the other 10 percent produces malojillo grass, the only other crop that can compete with sugarcane under present conditions on this high-priced productive land. Some of the best areas of these soils sell for more than $700 an acre without buildings or fences.

The soils in this group have been formed from material that is being washed continually from the hills of the interior and carried and distributed by the silt-laden (fig 124) overflowing streams, thus contin-

FIGURE 124.—Some of the Toa soils of the river flood plains along Río Cibuco. These soils have been formed from water-transported erosional material which is continually being washed from the hills in the interior and carried and distributed by the silt-laden overflowing streams, thus continually enriching the Toa soils at the expense of the surface soil of the eroding hill land. Limestone "haystack" hills in the distance.

Algunos de los suelos Toa en los llanos de aluvión a lo largo del Río Cibuco. Estos suelos han sido formados con material transportado por las aguas de los montes del interior de la isla y distribuídos por los ríos cargados de limo al inundar las regiones adyacentes, enriqueciendo contínuamente los suelos Toa a expensas del suelo de la superficie de los montes. A lo lejos, mogotes de piedra caliza.

ually enriching these soils at the expense of the surface soils of the eroding hill land. As the speed with which water moves from the riverbank across the flooded area gradually diminishes, its carrying capacity also decreases, and the larger suspended particles, such as the sandy material, settle near the bank, forming a narrow ribbonlike sandy strip on both sides of the river, that soon attains a height of several feet above the surrounding land. The finest clay particles are carried far from the riverbank and settle in depressions near the

poorly drained coastal lowlands. Generally speaking, the farther from the riverbank, the heavier is the texture of the soil and the more imperfect is the internal drainage of the land.

The soils of the river flood plains are divided into two subgroups as follows: (1) Well-drained soils, or those fairly near the streams, and (2) poorly drained soils, many of which are far from the streams and closely associated with the better areas of poorly drained mineral soils of the coastal lowlands.

WELL-DRAINED SOILS OF THE RIVER FLOOD PLAINS

The well-drained soils of the river flood plains include areas of soil so productive that some gran cultura sugarcane crops have produced more than 100 tons of sugarcane, or nearly 13 tons of sugar to the acre. The soils in this subgroup have been derived from alluvial materials. They are not only well drained but are friable, and most of them are deep. Areas of these soils are nearly level. They occur along stream channels and are subject to overflow during periods of high water. The silt-laden floodwaters rejuvenate these soils and help to make them the most productive soils on the island.

This subgroup includes 37 soil types and phases of the Toa, Estación, and Viví soils of the humid region and the San Antón and Altura soils of the arid and semiarid regions, in addition to riverwash, which occurs in both the humid and arid regions.

The Toa soils are derived from materials washed from the limestone hills and from the Múcara and associated soils, and, therefore, they are neutral or only slightly acid in reaction. They are high in bases and plant nutrients, even though some of them have been in nearly continuous cultivation to sugarcane (fig. 125) for about 380 years. They are friable brown soils from the surface to a depth below 4 feet.

The Estación soils are derived from materials washed from the Catalina and associated red and purple acid soils. Therefore, these soils also are slightly or strongly acid and are grayish brown. They are lower in bases and slightly inferior to the Toa soils in content of plant nutrients.

The Viví soils are developed from materials washed from the granite hills, and they are, therefore, gray, gritty, and very acid. Soils with acid reactions generally indicate that plant nutrients become available rather slowly and that the soil solution thus formed is diluted. Soils with alkaline reactions generally indicate the reverse. The Viví soils are lower in bases and content of plant nutrients than are either the Toa or the Estación soils.

The San Antón soils are developed from materials washed from the Descalabrado, Aguilita, and associated soils within the arid region. These soils are alkaline or calcareous, friable, brown, and granular. With irrigation and fertilizers they produce higher yields of sugarcane than do the Toa soils.

The Altura soils are derived from the same kind of material as the San Antón soils, but they occupy areas receiving a slightly greater average annual rainfall and therefore have a darker surface soil. In their natural condition they have a higher content of organic matter and plant nutrients than do the San Antón soils. With irrigation and fertilizers, the best areas of these soils should produce the highest yields of sugarcane on the island.

Physically and probably chemically the well-drained soils of the river flood plains are the best soils for sugarcane, as they are nearly level, have good drainage, and are friable, deep, and almost ideal for maximum agricultural utilization. These soils allow cultivation of all the land and the use of any type of modern machinery. The surface soils are loose, porous, and easily cultivated either with machinery or by hand. Water can penetrate rapidly, and there is enough silt and clay in the subsoil to cause the retention of large quantities of water. Although these soils contain considerable organic matter and

FIGURE 125.—Some of the Toa soils along the Río Bayamón that have been in continuous cultivation for about 380 years. Yields are higher than ever before, owing to good soil management, excellent cane varieties, fertilization, and constant control of insects and diseases. Recently this field has been planted to sugarcane in 24-inch square holes in a modified grand-bank system. The land generally is in cane or in the process of being planted to cane.

Algunos de los suelos Toa a lo largo del Río Bayamón, sembrados contínuamente de caña por más o menos 380 años. Los rendimientos son más altos que nunca debido a la buena administración, excelentes variedades de caña, abono y constante represión de los insectos y enfermedades. Recientemente este campo ha sido sembrado de caña en hoyos cuadrados de 24 pulgadas en un sistema de gran banco. Esta tierra está generalmente sembrada de o preparadá para caña.

plant nutrients, crop yields are greatly increased by applications of fertilizers and manure. These well-drained soils will support a wide diversification of profitable crops, but sugarcane is the most profitable judging from current practices, as more than 95 percent of these soils is planted to this crop. Yields of sugarcane range from 35 to 105 tons to the acre when the land is properly fertilized and irrigated.

Toa silty clay.—Toa silty clay is a highly productive alluvial soil occurring along many of the streams from Aguada to Río Manatí, as well as along the streams in the eastern and western coastal regions. The cultivated soil has a dark grayish-brown medium-friable granular neutral silty clay surface soil, about a foot thick, and a 12- to 16-inch brown clay subsoil, which is slightly more plastic than the surface soil but very retentive of moisture. In places the lower part of the subsoil is slightly mottled with rust-brown stains. The substratum becomes slightly more friable with depth, and in most places the water

table is below a depth of 6 feet, but it may be nearer the surface during high-water periods. This soil requires more careful cultivation than any other Toa soil, as it has the heaviest surface soil and subsoil. If plowed or worked at about the right moisture content, however, a very good tilth is formed, that enables both roots and water to penetrate deeply.

This soil near Aguada has a purple cast in all layers, because it has developed from material washed from the brownish-purple Malaya soils a short distance to the south.

Nearly the entire area of Toa silty clay is in sugarcane (fig. 126), and under irrigation yields may be as much as 70 tons an acre. The P. O. J. 2878 variety does better on this soil than on the other Toa

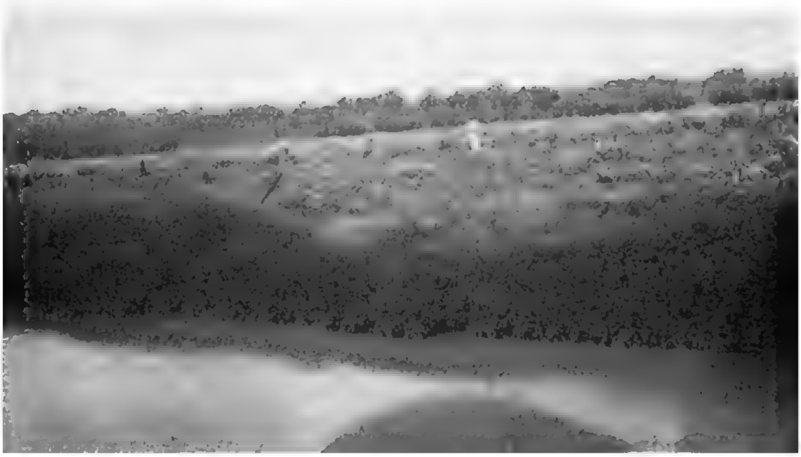

FIGURE 126.—Field of young sugarcane on Toa soils along the Río Cibuco.
Campo de caña joven en suelos Toa, a lo largo del Río Cibuco.

soils. It is competing with B. H. 10 (12), but so far decidedly the largest acreage is in the latter variety.

Toa silty clay loam.—In general, Toa silty clay loam is even more productive than Toa silty clay. It occurs throughout nearly all of the stream bottoms that receive material washed from the Múcara, the Colinas, or associated soils. It has a 12- to 18-inch dark grayish-brown friable granular silty clay loam surface soil, underlain to a depth of 30 inches by slightly heavier more plastic material. Below this layer the soil material is very similar to the surface soil, but it does not contain so much organic matter and is lighter in color. In places thin strata of gravel occur below a depth of 2 feet. This soil is considered a very good soil for sugarcane. It occurs in rather large areas, is easily cultivated, and produces good yields of sugarcane, both gran cultura and ratoons.

Toa silt loam.—On the average, Toa silt loam is the best soil for sugarcane in the humid and subhumid parts of Puerto Rico. An acre yield of 75 tons of gran cultura is possible during favorable years, and even this high yield may be increased with irrigation. This soil differs from Toa silty clay loam in that it is less heavy in all layers and has a more solid light-brown color in the subsoil. The land can be worked under more adverse moisture conditions than the heavier textured Toa

soils. B. H. 10 (12) is the best variety of sugarcane thus far tried on this soil. Toa silt loam is too friable for P. O. J. 2878 to obtain a firm roothold, as this variety of sugarcane is uprooted readily during high winds. This soil responds to fertilizer and irrigation. It is well drained, and sugarcane is usually planted in furrows. The silt loam is slightly more acid than the heavier textured soils of the Toa series.

Toa silt loam, low-bottom phase.—Areas of Toa silt loam occupying positions that are overflowed frequently are mapped as a low-bottom phase. The frequent inundation has both beneficial and detrimental effects. The muddy waters from the streams deposit more or less fertile material on these lowlands, thus tending to maintain fertility. Sometimes, however, loose coarse sand and gravel are deposited, thereby reducing the value of the land, and at times the force of the rushing water damages crops and erodes a part of the soil. Most of the areas that are very frequently overflowed are in pasture of malojillo grass, which grows very well and produces sufficient grass to maintain three or four cattle on an acre during the year. If the grass is cut and fed to the animals, an acre of land will furnish enough feed for four or five animals.

Toa loam.—Toa loam is a fairly extensive soil on the flood plains of Río Arecibo. It occurs also in other parts of the island. It is easier to cultivate than the heavier textured soils of the Toa series, but it is more acid and produces slightly lower yields in dry years. It contains more sand in all layers than does Toa silt loam, and in places it has a more stratified gravelly subsoil. B. H. 10 (12) is the variety of sugarcane most commonly grown on this soil.

Toa fine sandy loam.—Toa fine sandy loam occurs in many widely separated level areas adjacent to the streams, in the humid and subhumid parts of the island. It has a grayish-brown friable single-grain fine sandy loam surface soil that in many places ranges from 10 to 15 inches in thickness. The subsoil is brown firm, but not compact, loam or clay loam that gradually changes at a depth of about 30 inches to loose friable layers of sand and fine gravel. The material in all layers is slightly acid but not so much so as in the Estación soils.

Owing to the loose open friable character of this soil, cultivation is never long delayed after a rain, and the land can be plowed at almost any moisture content without danger of harming its structure.

This soil is not so well adapted to the production of high-yielding sugarcane as the heavier textured soils of the Toa series, because it does not have so high fertility or so great water-holding capacity. It does produce good yields of tobacco and minor crops. Areas of this soil that are planted to tobacco and protected from serious damage from overflows, however, yield as high as 1,200 to 1,800 pounds to the acre.

Toa fine sandy loam, low-bottom phase.—Areas of Toa fine sandy loam that are frequently overflowed are mapped as a low-bottom phase. This soil has about the same profile as the typical soil, but all layers contain slightly more gravel. Areas of this soil occur adjacent to large streams at an elevation not very much above the normal flow of the river.

This soil is used almost entirely as pasture land for the work oxen owned by the sugar centrals. In some places the oxen are kept on picket ropes, but in most places they graze over the entire pasture. Malojillo grass, which grows continuously and is the best grass adapted

to this land, furnishes 6 or 7 tons of hay an acre when cut every 2 or 3 months, or has a carrying capacity of several animals to the acre during the year. The few acres of this soil that have been planted to sugarcane produce better yields than the typical soil, but the risk of floods is so great that nearly 90 percent of the land is in grass for hay or pasture.

Estación silty clay.—Estación silty clay is a productive soil for sugarcane. It yields nearly as much as does Toa silty clay, the soil it most closely resembles.

A freshly plowed field of this soil shows many irregular-shaped gray or light grayish-brown rather dense clods, but after the first or second dashing tropical shower the fields have a good tilth, as the clods soon slake to a fine-granular structure. The gray or grayish-brown silty clay material constituting the 6- or 8-inch surface soil is granular and friable, and these characteristics, combined with the warm moist climate, make a favorable condition for the sugarcane to germinate quickly and extend its roots in all directions. The subsoil consists of grayish-brown friable silty clay, and, although it is slightly heavier than the surface soil, it allows rapid penetration of plant roots and percolation of water. It is heavy enough to have a high water-holding capacity, which provides a reservoir for a supply of moisture for the sugarcane roots during dry periods. The lower subsoil layer, or substratum, from a depth of 20 inches to a depth of several feet, is brown friable acid massive silt loam containing some plant roots in the lower part, showing that conditions are favorable for the roots to penetrate deeply in response to water, plant nutrients, or both.

This soil is rather easy to cultivate but not so easy as the lighter textured soils of the Estación series. It occurs in level areas adjacent to streams near the foothills or mountains in the vicinity of Mayagüez and Añasco. Most of the areas are planted to sugarcane or have been prepared for this crop. The common practice is to plant the sugarcane in furrows in this friable loose soil and fertilize with about 400 pounds of 12–6–8 when the sugarcane is 1½ months old, then to apply 400 pounds of ammonium sulfate about 2 months later. The varieties of sugarcane most commonly grown on this soil are B. H. 10 (12) and P. O. J. 2878. Both do very well. They yield from 40 to 55 tons to the acre in primavera plantings and from 30 to 35 tons in ratoons.

Some areas of Estación silty clay have so much gravel and small rounded stones on the surface and throughout the profile that their crop adaptation differs from that of the typical areas. The gravelly patches are shown on the map with gravel symbols. Some of these nontypical areas have bands of gravel in the subsoil and substratum. This gravelly soil is much less suited for crop production and is more difficult to cultivate than the typical soil. It occurs in small areas in the western part of the island and is frequently covered with water. It is used mostly for pasture land, and the grass grows very well if the weeds are kept in check.

Estación clay loam.—Estación clay loam occupies only a few small areas, mainly in the eastern part of the island and near Ciales. It is similar in physical and chemical characteristics to Estación silty clay, but it contains less silt and clay and more sand in all layers.

This soil is characterized by a grayish-brown strongly acid friable cloddy clay loam surface soil about 8 or 10 inches thick. This is underlain by a brown acid clay loam or silty clay loam subsoil, 10 or

12 inches thick, which is medium plastic when wet. This layer, in turn, is underlain by brown or grayish-brown friable silt loam or loam containing some thin strata of fine sand and gravel. All layers are very acid, and when the surface soil becomes wet it bakes to a greater extent than does the surface soil of the Toa soils.

The soil is easily cultivated, and roots penetrate to great depths. The largest acreage is used for the production of sugarcane and tobacco, which grow very well.

Estación silt loam.—Estación silt loam is the most extensive soil of the Estación series. It is a fertile soil and produces high yields of sugarcane, the crop for which it is best adapted. It occurs adjacent to the larger streams throughout many of the better drained areas of the island.

The 8- or 10-inch surface soil is brown mellow friable acid granular or semigranular silt loam. It is underlain by a rich-brown somewhat heavier silt loam or clay loam subsoil ranging from 15 to 20 inches in thickness. In a few areas the subsoil consists of medium-compact heavy silty clay loam which is less well drained than the average area of this soil. Below a depth ranging from 30 to 40 inches are stratified beds of gravel. Along some of the streams of the interior, the surface soil has a tendency to bake at the surface, if the land is not properly cultivated.

This soil is used extensively for the production of sugarcane and to less extent for tobacco and minor crops. The average acre yields are about the same as on Toa silt loam. This soil responds to an application of 2 or 3 tons of lime every 3 or 4 years, especially for sugarcane.

Some areas of Estación silt loam have so much gravel and large cobblestones scattered on the surface and throughout the profile that their agricultural use is limited to the growth of grass and brush. Such areas are shown on the soil map by gravel symbols. Some of the gravelly areas are not flooded very frequently now, but in years past they must have been influenced by fast-flowing waters from the interior, judging from the presence of large boulders scattered promiscuously over the surface.

Estación silt loam, low-bottom phase.—Areas of Estación silt loam that occupy a low position adjacent to the streams are flooded often and are mapped as a low-bottom phase. Not only are such areas more gravelly and more difficult to cultivate than the typical soil, but the risk of having the crops washed away or drowned is so great that most of this low land either is in pasture or is idle and becoming covered with brush and weeds.

Estación loam.—Estación loam, to a depth of 10 or 12 inches, is brown or light-brown granular friable acid loam. Some spots, particularly in the pastured areas, are slightly darkened with organic matter in the surface layer. The subsoil, to a depth ranging from 20 to 30 inches, is yellowish-brown loose friable semigranular acid light loam or sandy loam. The substratum consists of stratified beds of sand and gravel. In many places both the surface soil and subsoil are intermixed with large rounded gravel and cobblestones.

This soil occurs along Río Mameyes and Río Fajardo in the northeastern part of the island and along Río Grande de Añasco in the western part.

The areas of Estación loam are nearly level, although in the virgin condition they are modified by small irregular hummocks. This soil

lies adjacent to streams and frequently is overflowed. Stones and some boulders are scattered over the surface.

Probably 50 percent of Estación loam is in cultivation to sugarcane, and the remainder serves as range for cattle and goats. The deeper and better areas are used for sugarcane, which yields from 35 to 45 tons an acre when the land is properly managed, limed, and fertilized. As areas of this soil range from well to excessively drained, the sugarcane is planted in furrows. In dry years, yields of sugarcane are very low, and even the grass is short. Estación loam is considered much less valuable than Estación silt loam.

Areas of Estación loam shown on the soil map with gravel symbols are similar to typical Estación loam in color, structure, and depth, but in texture they differ in that they contain more fine gravel from the surface to considerable depth. The surface soil is similar to that of the typical soil but contains a conspicuous amount of fine gravel and rock fragments both on the surface and throughout the soil material. The subsoil and substratum are the same as in the typical areas. This more gravelly soil occurs in small level areas in the western part of the island, adjacent to streams that carry considerable material washed from the Catalina and related red acid soils of the interior. It is used less extensively than the typical soil for the production of sugarcane but more extensively for pasture. Because of its porous loose nature it is best adapted to shallow-rooted truck crops and pasture, which grow very well, as the soil receives more rainfall than most areas of the typical soil.

Many areas of Estación loam that are very close to streams are flooded more frequently than the rest of the land. These areas are not shown separately on the map. This included soil has a 6-inch brown loose porous acid loam surface soil, overlying brown incoherent fine sand, which continues to a depth below 4 feet. Considerable sand, gravel, and rocks are on the surface and throughout the soil layers. This is not so desirable a soil as either the typical soil or the gravelly areas because it contains more stone and also is subject to frequent inundations during the year. Probably 10 percent of it is used for the production of sugarcane and minor crops, and the remainder is in range for livestock. The native vegetation consists of weeds, small brush, and grass. This included soil is constantly changing, both in position and in quality. Some high floods deposit large quantities of silt and clay, and other floods cut new channels across the land and carry away large quantities of material. In most places the relief is uneven.

Estación sandy loam.—Estación sandy loam has a 6- or 7-inch brown or light-brown loose friable single-grained acid sandy loam surface soil, underlain by yellowish-brown acid loamy sand, which continues to a depth ranging from 20 to 30 inches. The substratum consists of stratified sands and gravel.

This soil occupies small narrow nearly level strips adjacent to the streams of the interior. Owing to the distance from roads and to its sandy texture, this soil is used more extensively for the production of tobacco and truck crops than for sugarcane. It is not so productive as Toa fine sandy loam and requires more lime and fertilizer in order to maintain its fertility.

Areas of Estación sandy loam that have gravel and small cobblestones scattered over the surrace and throughout the profile are shown

on the soil map with gravel symbols. These areas include only a few acres each and are used mostly for range pasture for cattle. This gravelly soil is only slightly better than riverwash.

Riverwash.—Riverwash consists of sandy and gravelly areas along the larger streams that frequently overflow their banks. In fact most of this land is covered with water to a depth ranging from 2 to 10 feet during protracted rains. Areas that are too loose, porous, sandy, and gravelly to be used for agricultural purposes are included with riverwash on the map. Most of the areas of riverwash are devoid of vegetation. Some of the gravel is used in concrete construction work, but, generally speaking, riverwash is wasteland, lying for the most part not much higher than the normal flow of the rivers, and much of it is within the channels of the rivers. In places cobblestones and large boulders are numerous on the surface. Some areas of this land are dry and droughty many months of the year; for example, areas associated with the San Antón soils along the south coast.

Viví clay.—Vivi clay is derived from recent alluvial material that has been washed from granitic hills. It is somewhat like Toa silty clay but is more acid, lighter colored, and more gritty. It occurs in a few very small level areas adjacent to streams, mainly east of Naguabo and near Yabucoa.

The surface soil, to a depth of 6 or 8 inches, is light grayish-brown cloddy but friable acid clay, underlain by light brownish-gray friable acid clay containing some yellowish-brown and gray splotches of gritty sandy clay in the lower part. This layer is underlain, at a depth ranging from 24 to 30 inches, by gray friable sandy clay mottled with sandy material. The water table lies at a depth ranging from 40 to 60 inches, but it is within reach of the lower roots of sugarcane. With some subirrigation and with the rather heavy annual rainfall on areas of this soil, yields are seldom reduced because of lack of moisture. The physical characteristics of the surface soil, subsoil, and substratum are such that sugarcane roots can ramify unrestricted to considerable depths, and as the plants approach maturity there is a generous root development in all layers. If the climatic conditions, physical characteristics, and relief are nearly ideal, the limiting factor in production must be due to chemical deficiencies, such as a deficiency of available plant nutrients. Soils derived from granite in high-rainfall areas generally are low in plant nutrients. Much of the available bases and plant nutrients are leached from the soil in the process of soil development and transportation from the hillsides before the soil is deposited on the alluvial flood plains.

Viví clay yields fairly well when heavily fertilized, but it requires more fertilizer than Toa silty clay, and even under such treatment it seldom produces as high yields as does the Toa soil.

Viví silty clay loam.—Viví silty clay loam occurs chiefly in a small area northwest of Utuado along Río Grande de Arecibo. This soil is similar to Viví clay in relief and chemical qualities, but in physical characteristics, especially texture, it differs from that soil, in that all layers are slightly more gritty and contain less clay. As most areas of this soil are far from a sugar central, nearly the entire area is used for the production of tobacco, yields of which range from 800 to 1,200 pounds to the acre.

Viví clay loam.—Viví clay loam is predominantly a friable deep well-drained acid gray or grayish-brown soil occurring on river bottoms

and derived from granitic materials. It is not nearly so heavy in texture as Viví clay or Viví silty clay loam, but in all other respects it is similar. It occurs in the eastern part of the island and is used almost entirely for the production of sugarcane. When the land is properly fertilized and cultivated, yields of sugarcane range from 45 to 55 tons of gran cultura to the acre.

Viví clay loam, shallow phase.—Areas of Viví clay loam that have excessively sandy stratified subsoil layers are mapped as a shallow phase. This soil occurs in ribbonlike strips following old stream channels in valleys within the large granitic area in the eastern part of the island. This soil is more droughty, more difficult to farm, and less productive than the typical soil. Nearly all of it is used for the production of sugarcane.

Viví silt loam.—Viví silt loam is very closely associated with Viví silty clay loam along the Río Viví and the Río Grande de Arecibo, near Utuado. It has a fairly uniform color, structure, texture, and consistence from the surface to the stratified sand and gravelly layers that occur below a depth of 30 inches. The soil material is uniformly grayish-brown semigranular friable silt loam, which is very acid and low in fertility. Most of this soil is in continuous cultivation to tobacco, corn, beans, or sweetpotatoes. Crop yields are better than those obtained on Viví sandy loam but less than on Toa silt loam. This soil is easily cultivated, and it responds readily to complete fertilizers, lime, manure, and green-manure crops. It should be a good soil for the production of bright tobacco.

Viví loam.—Viví loam is the most extensively distributed soil of the Viví series. It occurs throughout nearly all of the alluvial flood plains that have been influenced by coarse-grained granitic materials.

A characteristic feature of this soil is that there is but little change in color, texture, structure, and consistence from the surface to a depth below 40 inches. It consists of friable permeable semigranular light grayish-brown gritty loam. The topmost 6- or 7-inch layer has the highest content of organic matter and the lower substratum the least. The acidity increases with increasing depth.

This soil is easily cultivated, and it can be worked under a wide range of moisture conditions without harming its structure. Plant roots and water readily penetrate to great depths. Viví loam is not highly productive because it is derived from materials washed from the granitic hills that were leached of their bases and plant nutrients before they were eroded from the hillsides.

The land use of this soil depends on its location. Nearly all areas in the vicinity of sugar centrals are used for the production of sugarcane, which yields from 30 to 50 tons an acre when well fertilized and cultivated. Areas at a great distance from a sugar central are used for the production of tobacco and coffee. Tobacco grows very well and produces from 800 to 1,000 pounds to the acre when well fertilized. After the tobacco crop is gathered, corn and beans are planted. They also yield fairly well but not nearly so well as on Toa loam. Coffee yields very well during favorable years. Crop yields depend to a great extent on the amount of rainfall and the number of inundations during the year. This soil can endure fairly long dry periods without serious decrease in crop yields. It also can accommodate especially heavy rains, provided too many inundations do not occur

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during the same year or too serious washings do not accompany the overflows. With equal overflows, areas of Viví loam are the least affected of the Viví soils.

Viví loam, shallow phase.—Areas of Viví loam that have sufficient gravel and coarse sand deposits within the profile to affect crop yields seriously during average years are mapped as Viví loam, shallow phase. These coarse-textured sandy deposits are the result of forceful overflows during former times, carrying large particles and rolling small rocks over the surface of the land, which later were covered by finer textured material. Now it is not unusual for torrential rains to overflow the riverbanks with such speed and force that new channels are cut through this soil or thick deposits of coarse material are heaped promiscuously into irregular-sized piles.

This soil requires much more moisture than the typical soil for equal crop production. Owing to the uncertainty of crop yields, due to drought or serious floodings, the land is used principally as range land for cattle and goats.

Areas of this soil that have much gravel on the surface are shown on the map with gravel symbols. Such areas are much less productive and less desirable than the typical areas. Most of the gravelly areas are near Patillas.

Viví sandy loam.—Viví sandy loam is nearly as widely distributed as is Viví loam, and the two soils are very similar in many respects. They differ in soil texture and crop yields. Viví sandy loam has a much lighter texture and is less productive. It is too loose, porous, and low in fertility for profitable yields of sugarcane. It produces from fair to good yields of minor crops and tobacco, and it would produce large grapefruit trees, but no commercial orchards were observed on it during the course of the survey.

Excessively gravelly areas are shown on the map with gravel symbols. Such areas are less productive than the typical areas.

Viví loamy sand.—Viví loamy sand is the lightest textured soil of the Viví series. It is confined mostly to the eastern part of the island and is associated with the other Viví soils. In general it occupies a position along the stream banks.

Viví loamy sand differs from Viví sandy loam in that it is more friable, more porous, less coherent, more acid, lower in fertility, and less valuable for all crops. Physically it is adapted to minor crops that do not require great fertility.

This soil is subject to frequent overflows, and it may become heavier or lighter in texture during some of the more forceful overflows, depending on the character of the material deposited on it.

San Antón clay.—San Antón clay is the most difficult of the San Antón soils to cultivate and plant, but, regardless of this handicap, nearly all of it is planted to sugarcane, the crop for which it is best adapted. This soil occurs along the south coast paralleling the streams but at a considerable distance from the riverbanks. It is subject to overflow during high floods and receives periodic deposits of sand, silt, and clay, which help to maintain its high productivity.

The 10-inch surface soil is friable firm slightly cohesive calcareous brown or dark-brown clay. When wet it is plastic, and when it dries large cracks appear on the surface. The subsoil, to a depth of 20 to 24 inches, is heavy but friable light grayish-brown calcareous silty clay or clay. Below this material is slightly less plastic but heavy

light-brown or grayish-brown calcareous silty clay loam, which continues to a great depth with little change. In places slight mottlings of iron stains occur, indicating restricted drainage.

This soil occurs in rather large flat areas and can be farmed efficiently with large modern machinery. Nearly all of it is planted to B. H. 10 (12) sugarcane, which yields from 60 to 75 tons to the acre when properly fertilized and irrigated. Although very few areas are affected with alkali, there are probably more such areas in proportion to the total area than of any other soil type in the San Antón series.

San Antón silty clay.—San Antón silty clay is considered one of the best soils for the production of sugarcane. The land is difficult to cultivate, owing to the high content of clay in the surface soil, but it responds to high applications of fertilizer, and when it is properly irrigated, good yields of sugarcane may be expected year after year.

This soil is characterized by a brown or grayish-brown nut-structured mealy heavy calcareous silty clay surface soil about 12 inches thick, which becomes plastic when wet. The subsoil is slightly heavier and more plastic than the surface soil, but it is not so compact that plant roots and water will not penetrate it rapidly. It is heavy enough and sufficiently thick to have a high water-holding capacity. It is brown, calcareous in reaction, and averages about 20 inches in thickness. Below this layer is fairly friable massive silty clay loam that continues to a depth of several feet before sand and gravel are reached.

The land uses of this soil and San Antón clay are very similar, and yields obtained on both soils are about the same. The fertilizer most commonly used is about 400 pounds of 12–8–4 for the first application and 400 pounds of ammonium sulfate as the second application.

San Antón silty clay, shallow phase.—The shallow phase of San Antón silty clay has a brown fairly heavy calcareous granular silty clay surface soil about 8 inches thick, underlain by light-brown fairly friable granular calcareous silty clay loam, which continues to a depth of about 20 inches. Below this depth are beds of stratified calcareous sands and gravels.

This soil is excessively drained, owing to the gravelly layers in the lower part of the subsoil and upper part of the substratum, and for this reason frequent irrigations are necessary. This soil is used almost entirely for the production of sugarcane, but yields are about one-half as large as those obtained on the typical soil, even if twice or three times the amount of water is applied to this shallow soil.

Areas of San Antón silty clay, shallow phase, occur adjacent to streams along the south coast, west of Salinas.

San Antón silty clay loam.—The 12-inch surface soil of San Antón silty clay loam is neutral friable uniformly grayish brown granular silty clay loam that is fairly easily plowed and works up to a good tilth. The subsoil, to a depth of 24 inches, is brown medium-friable, somewhat granular, heavy silty clay loam. This layer is the zone of maximum compaction, and generally a rather abrupt change in compactness exists between it and the surface soil. The substratum is friable, permeable, massive silt loam, silty clay loam, or clay loam, that is uniformly brown to a depth of several feet.

Owing to its responsiveness to fertilizers, its favorable texture and structure, nearly level relief, and depth of soil material, this soil is

very productive. Sugarcane occupies nearly 100 percent of its area, and yields range from 60 to 100 tons an acre, depending on the management of the land, the varieties planted, the amount of irrigation water available, and the fertilizers used.

This soil occurs only along the south coast, west from Guayama.

San Antón clay loam.—San Antón clay loam differs from San Antón silty clay loam in texture of the surface soil. In other respects these two soils are very similar, even as regards land use and crop yields.

This soil is characterized by a brown granular friable neutral or calcareous clay loam surface soil ranging from 8 to 12 inches in thickness, which is underlain by a permeable semigranular light-brown silt loam or clay loam subsoil about 14 inches thick. The substratum is interbedded with layers of silt loam, loam, and very fine sandy loam to a depth of 4 feet, and below this depth are stratified beds of sand and gravel.

In many places this soil sells for $500 an acre without any buildings. It occurs chiefly in the extreme southwestern part. Nearly the entire area is in sugarcane.

San Antón silt loam.—San Antón silt loam is one of the best soils in Puerto Rico for the production of sugarcane, that is if it is irrigated and fertilized. This soil has a friable brown granular silt loam surface soil about 10 inches thick, that has a fairly high content of organic matter and is nearly everywhere free from gravel and harmful salts. The soil material underlying the surface soil is so similar in texture, color, and composition that the division between surface soil and subsoil is not detectable. The substratum, below a depth of 24 inches, consists of light yellowish-brown friable semigranular very fine sandy loam or fine sandy loam. In a few places thin strata of gravel occur below a depth of 30 inches. The subsoil and substratum are heavy enough to prevent any serious leaching of fertilizers, yet they are not so heavy as to interfere with rapid penetration of roots. Underdrainage of this soil is good, and water never stands on or near the surface for any length of time unless irrigation practices are faulty.

When cultivated or plowed, this soil works into a loose granular condition, making an ideal seedbed. It can be worked under a fairly wide range of moisture conditions without harming its structure. Water penetrates rapidly, and, owing to the slightly heavy subsoil, a large proportion of it is retained and used by the lower roots of plants.

This soil occurs in rather large areas along streams from a point near Guayama to Guayanilla. Owing to its nearly level relief and its occurrence in extensive areas, large modern machinery can be used efficiently, thereby reducing the cost of cultivation. Consequently the value of this soil is increased. Some areas have sold for more than $700 an acre. Gran cultura yields of more than 100 tons to the acre of the B. H. 10 (12) variety of sugarcane have been reported in many years. The average acre yield of sugarcane on this soil is about 70 tons gran cultura and 40 tons first ratoon. At present the largest acreage is planted to B. H. 10 (12), but P. O. J. 2878 gives very good yields.

The fertilizer most commonly used is 400 pounds of 12–8–4 for the first application and 400 pounds of ammonium sulfate as a second application.

Often as much as 10 feet of irrigation water is applied to an acre of a 14- or 16-months gran cultura crop. The sugarcane is planted in furrows.

San Antón silt loam, shallow phase.—Areas of San Antón silt loam that are underlain by gravel at a depth of less than 30 inches are mapped as a shallow phase. The physical and chemical properties of the surface soil are about the same as those of the typical soil, but the gravel in the subsoil greatly reduces yields on this shallow soil. The productivity of the land is more or less directly in proportion to the depth to gravel. The nearer the gravel is to the surface, the lower the yield.

This soil requires several times as much irrigation water as does the typical soil, and therefore the cost of producing a ton of sugarcane on the shallow soil is higher than on the typical soil. About 50 percent of this soil is used for the production of sugarcane, and the remainder is in native pasture grass.

San Antón loam.—San Antón loam differs from San Antón silt loam only in that it has a lighter textured surface soil. The loam is more easily cultivated than the silt loam, but it requires slightly more water to produce the same tonnage of sugarcane. Nearly the entire area of this soil that can be irrigated is used for sugarcane.

Agriculturally this soil and the silt loam rank very close together. Both are very valuable and very productive. (See fig. 17.)

San Antón loam, shallow phase.—San Antón loam, shallow phase, is closely associated with San Antón silt loam, shallow phase. It differs from that soil in the texture of the surface soil. The shallow phase of San Antón loam as shown on the map includes some areas that have a fine sandy loam surface soil.

All areas of this shallow soil are exceedingly droughty, and for fair or even medium yields many irrigations are necessary. With proper fertilization and from 10 to 15 acre-feet of water, this soil produces from 35 to 40 tons of sugarcane to the acre. About 60 percent of the land, however, is not irrigated and is used for pasture. The grass is of good quality, but during dry seasons it soon becomes brown, and the average carrying capacity of the pastures is less than on some of the soils used for grass in the inner plains.

San Antón fine sandy loam.—San Antón fine sandy loam is one of the less productive San Antón soils for sugarcane. It is characterized by a brown loose friable fine sandy loam surface soil about 10 inches thick, which is underlain by a layer of brown or grayish-brown friable permeable loam or fine sandy loam, from 12 to 15 inches thick. The substratum, to a depth ranging from 3 to 4 feet, consists of loose mellow fine sand or fine sandy loam. Water and plant roots penetrate this soil readily. Very few areas are contaminated with soluble salts. Nearly the entire area is used for sugarcane. This soil would be very good for grapefruit or many kinds of truck crops.

Altura clay.—Altura clay differs slightly from both the San Antón and the Toa soils. It occupies a position adjacent to streams along the foothills of the southern coast, mainly west of Salinas. It receives more average annual rainfall than the San Antón but less than the Toa soils. The surface soil is darker and less alkaline than the San Antón soils, but the soil is more alkaline in all layers than are the Toa soils.

If this soil is examined in a recently plowed field, it has a uniform very dark grayish-brown or black cloddy but fertile appearance. The 10- to 12-inch surface soil is granular friable nearly black neutral clay, which becomes mellow when worked at the proper moisture content. This layer is underlain by grayish-brown or brown slightly firm alkaline clay, which continues to a depth of 30 inches. The substratum is brown calcareous clay loam, in many places stratified with sand and gravel layers below a depth of 4 feet.

This soil has a higher content of organic matter than either the San Antón or Toa soils, and for that reason it is slightly more desirable. It is not very extensive. Nearly the entire area is irrigated and used for the production of sugarcane, the crop for which it is best adapted. The difference in yield between crops on this soil and on San Antón clay is slightly in favor of this soil.

Altura silty clay.—Altura silty clay occupies nearly level positions adjacent to streams along the southern coast and extends inland from the sea. The most important difference between this soil and Altura clay is in the texture of the surface soil. This textural difference makes Altura silty clay easier to plow, irrigate, and cultivate. Crop yields on the two soils are about equal.

Altura silt loam.—Altura silt loam is the best soil for the production of sugarcane, but unfortunately it occupies only a few hundred acres. It differs from San Antón silt loam in that it has higher natural productivity and therefore does not require so much fertilizer in order to produce the same yields.

This soil is characterized by a very dark grayish-brown or nearly black granular friable neutral surface soil about a foot thick, which works into an excellent tilth when plowed and cultivated. The brown subsoil is slightly heavier and is alkaline in reaction. It is sufficiently permeable for roots and water to penetrate readily to a depth of several feet, but it is heavy enough to hold sufficient water for plant roots during dry periods or between irrigations. This layer is underlain, at a depth of about 30 inches, by friable brown calcareous loam, which continues to a depth of several feet before gravel or the water table is reached. This soil is high in organic matter, is easily tilled, absorbs water readily, is easy to irrigate, and is very productive, year after year, when well managed. Very few areas are affected with alkali.

Nearly 100 percent of this soil is planted to sugarcane, which produces an average of 75 tons to the acre of gran cultura when irrigated and fertilized with from 400 to 600 pounds of fertilizer to the acre.

Altura loam.—Altura loam is developed from alluvial material that has been washed from the steep hills of the southern side of the Cordillera Central. It occurs in several areas near the foothills between Guayama and Juana Díaz. With the exception of the texture of the surface soil, this soil corresponds with Altura silt loam. It is slightly less productive than the silt loam, but nevertheless it is one of the most productive soils, and nearly the entire area is used for the production of sugarcane—that is, all areas that can be irrigated.

Altura loam, shallow phase.—The shallow phase of Altura loam resembles the typical soil, but it has stratified sand and gravel at a depth of less than 24 inches. This gravel substratum greatly reduces the value of the soil for all commercial crops. Nearly prohibitive

amounts of water are required in order to keep the crops from burning during long dry periods. Therefore most areas are not irrigated and are used only for pasture, which has a carrying capacity of two bullocks to 3 acres. Most areas have been planted to guinea grass, and the cattle roam at will. The quality of the grass is excellent. Dug wells and water from concrete-lined irrigation canals supply water for the livestock.

POORLY DRAINED SOILS OF THE RIVER FLOOD PLAINS

The poorly drained soils of the river flood plains include 39 soil types and phases of the Coloso, Fortuna, Martín Peña, and Vega Baja series, which occur in the humid and subhumid sections along the western, northern, and northeastern coasts; the Josefa, Irurena, Maunabo, Yabucoa, and Talante soils, which occur along the humid eastern coast; and the Aguirre, Guánica, and Vayas soils, which occur along the semiarid southern coast.

All the soils in this group are at an elevation of only a few feet above sea level, and in many of them the water table is constantly at a depth averaging less than 24 inches from the surface. Most of the areas are subject to frequent inundations and sedimentations. They are nearly level, and, as they have been formed by the slow accumulation of sediments carried by water from the hillsides of the uplands and deposited in comparatively quiet shallow water, they are heavy textured to considerable depth. Many of the soils are so closely associated that there is no definite line of demarcation between any two adjoining soils.

Most of the soils in this group occur as low imperfectly or poorly drained flat areas between the well-drained soils of the river flood plains and the soils of the coastal lowlands. From 80 to 85 percent of their area is used for the production of sugarcane, the leading variety of which is B. H. 10 (12). Most of the remaining 15 to 20 percent is used for growing malojillo grass to be cut for dairy cattle or to be pastured by either work oxen or dairy cattle.

The machinery used in cultivating the sandier soils of the group is the same as that used on the well-drained alluvial soils, but on the heavy-textured soils considerable work is done by hand labor, which increases the cost of production. If the heavy-textured soils are cultivated when wet the soil becomes puddled, and large clods are formed. Mechanically, several harrowings are necessary to break the clods, but, owing to the character of the severe sudden tropical storms, the rain penetrates the clods and they slake readily after two or three rainstorms.

The subsoils of these soils are heavy. In most places they are mottled with rust brown and gray. In some of the more poorly drained areas, the color is solid gray or even blue gray in the lower layers. A high proportion of the total area of the heavy-textured soils of the group requires artificial drainage. This is accomplished in most places by a few large ditches and many small ones.

The grand-bank system is the most commonly practiced method for planting sugarcane. B. H. 10 (12) is the best variety that has been tried on a large commercial scale. During dry years the well-managed heavy-textured soils of the group are more productive than the unirrigated soils of the well-drained river flood plains. This is because the heavy subsoil is able to hold sufficient water to sustain the sugar-

cane roots during the dry period better than do the subsoils of the less heavy well-drained alluvial soils; also because, owing to the nearness of the water table to the surface, some roots are able to reach water during droughts. In wet years, drainage of the poorly drained phases of these soils, owing to the high water table, becomes a serious problem, and sometimes much sugarcane is drowned during protracted wet periods. During abnormally wet years these soils are less productive than the well-drained alluvial soils. Deep knifing would be beneficial for a short period only, owing to the plastic consistence of the heavy sticky clay, which causes it to run together soon after the frequent rains.

The Coloso soils are derived from neutral fine-textured materials washed from the Múcara, Colinas, and associated soils that are derived from fine-grained volcanic rocks and limestone. The Coloso soils are poorly drained associates of the Toa soils. They are deep, stone-free, highly fertile, neutral, and plastic. Most areas have a heavy texture, a high water table, a dark surface soil, and a mottled gray, bluish-gray, and rust-brown subsoil.

The Fortuna soils are similar to the Coloso soils, but they are derived mainly from sediments washed from the acid Catalina and related red soils and are therefore more acid and more brown than the Coloso soils. They bear the same relationship to the Estación soils that the Coloso soils do to the Toa soils.

The Vega Baja soils occupy an intermediate position between the soils of the coastal plains and those of the river flood plains and therefore have some characteristics of both. These soils are characterized by a dark-colored medium-plastic slightly acid sedimentary material underlain at a depth of about 18 inches by plastic strongly acid mottled red, gray, and yellow coastal-plain material. They are less productive than either the Coloso or the Fortuna soils and are seldom flooded.

The Martín Peña soils are similar to the Vega Baja soils, but they occupy slightly lower positions and are, therefore, more frequently subject to floods and a higher water table. The soils of the Martín Peña series are the least productive soils of these three closely associated series—the Coloso, Vega Baja, and Martín Peña.

The soils of the Talante, Irurena, Yabucoa, Josefa, and Maunabo series occur principally in the valleys of the southeastern part of the island, where the soils have been influenced by granitic materials washed from the adjacent uplands. The soils of these five series are similar in many characteristics, and the transition between any two adjacent soils in many places is so gradual that the boundary lines are drawn arbitrarily.

During exceptionally heavy torrential rains many areas of these soils become inundated, and the force of the water flowing across the flooded valleys alters the courses of the streams in many places and also intermixes the soil material so as to change the soil texture and in some places even the soil series. The soils within these valleys may be considerably different 10 or 20 years from now. The soils most likely to be affected are those adjacent to or near the streams in the upper parts of the valleys.

The Talante soils are derived from coarse-grained granitic material, and therefore they are gray, friable, and low in plant nutrients. They bear the same relationship to the well-drained Viví soils as the

Coloso and Fortuna do to the Toa and Estación soils, respectively. The Talante soils are closely associated with the Viví soils but in general occupy a slightly lower position, farther from the stream bank.

The Irurena soils differ from the Talante soils in that they have darker brown surface soils, a slightly higher proportion of fine-textured material in all layers, and a higher water table.

The Yabucoa soils differ from the Irurena soils in that they have lighter colored surface soils and are less well drained, especially in the substratum.

The Josefa soils bear the same relationship to the Yabucoa soils as the Talante soils do to the Viví soils; that is, they are more poorly drained than the Yabucoa soils and have mottled gray and brown surface soils.

The Maunabo soils occupy an intermediate position between the poorly drained soils of the river flood plains and the soils of the coastal lowlands. They have some characteristics of the soils of each group, but they more closely resemble the Josefa and Yabucoa soils than the Palmas Altas soils, and therefore are placed in this group. At times they are subject to fairly long periods of inundation.

The Vayas, Aguirre, and Guánica soils occur throughout the valleys of the arid and semiarid districts, and therefore they are alkaline, dark colored, and high in plant nutrients. These soils, when properly managed, are very productive—more so than any other soils in this group. In some places the content of harmful salts is sufficient to be injurious to the production of most cultivated crops. These soils require both irrigation and drainage for the best land use.

The Vayas soils are the poorly drained associates of the San Antón soils. They are brown or dark grayish-brown granular deep highly productive soils occupying nearly level areas adjacent to or near stream channels, generally near the sea, where the elevation is only a few feet above sea level and the water table is fairly near the surface.

The Aguirre soils of the arid sections correspond very closely to the Coloso soils of the humid sections. They are influenced slightly more by estuary deposits and to less extent by alluvial deposits than are the Coloso soils. In color, texture, and physical characteristics they are similar.

The Guánica soils are similar to the Aguirre soils, but in them the water table is much nearer the surface, and the soils, therefore, are darker, slightly heavier, and more poorly drained.

Coloso clay.—Coloso clay is one of the more extensive soils of the Coloso series, as it occurs throughout nearly all of the alluvial lands in the humid and subhumid sections. It is a very fertile soil and is especially productive for sugarcane when it is adequately drained.

In a plowed field the 10- or 12-inch surface soil is dark grayish-brown neutral clay with a fragmental structure. It is plastic when wet and cloddy when dry. The subsoil, which continues to a depth of about 30 inches, is mottled gray and grayish-brown plastic neutral clay that usually is wet. The substratum continues to a depth of several feet and is similar to the subsoil, but it is slightly more friable. In places, especially where this soil grades into its poorly drained phase, it is bluish gray. In most areas the water table is between depths of 30 and 40 inches from the surface.

In some places in the vicinity of Cabo Rojo, areas mapped as Coloso clay contain narrow beds of fine sand intermingled with the

normal clay material below a depth of 18 inches. As these beds of sand occur only in local spots, they do not interfere with crop yields or the land use.

Nearly the entire area of Coloso clay is used for the production of sugarcane, and, under normal rainfall conditions, it is very productive year after year. The production for gran cultura sugarcane is from 50 to 65 tons to the acre when the land is properly fertilized and cultivated. The most commonly used fertilizer is from 400 to 600 pounds of 12-6-5 an acre, applied when the sugarcane is about 2 months old, and from 400 to 600 pounds of ammonium sulfate applied 2 months later. The most important variety of sugarcane grown is B. H. 10 (12). Nearly all of this soil is ditched by hand for grand-bank planting.

Coloso clay, poorly drained phase.—Areas of Coloso clay in which the water table is near the surface are classified as a poorly drained phase. This soil differs from the typical soil in that it is more poorly drained and therefore contains more gray mottlings in the surface soil and has a more bluish gray lower subsoil layer. This soil expands and contracts at the extremes of moisture content, and a dry cut in a ditchbank has numerous wide cracks, both vertical and horizontal, from the surface to a depth of several feet. This shows that the soil is very plastic and requires careful attention when cultivated and plowed.

Coloso clay, poorly drained phase, is more deeply covered by floods and remains under water for a longer period than does the typical soil. The most successful planting method used for sugarcane is the grand-bank system. Sugarcane yields from 40 to 55 tons to the acre when it is well fertilized and properly managed. Most of this soil is used for the production of sugarcane, but some areas are producing dense growths of malojillo grass. In general, this grass is grown during the so-called rest period, after which the land is replanted to sugarcane. The carrying capacity of the pasture is about three head of oxen to the acre when the animals are allowed to run loose in the fields. If the grass is cut and fed to them in the stables, 1 acre will supply enough feed for four or five animals.

Coloso silty clay.—Coloso silty clay differs from Coloso clay in that it is less heavy textured in all layers. It generally yields a few more tons of sugarcane to the acre, is easier to cultivate, and requires less drainage than does Coloso clay. In some places this soil is irrigated, and, under such conditions, yields of 65 tons an acre of fall-planted sugarcane are not uncommon. B. H. 10 (12) is the most common variety of sugarcane grown, although high tonnages of P. O. J. 2878 and F. C. 916 have been reported.

This soil is extensive along the streams of the river flood plains in the western and northern parts of the island. About the only variations that occur throughout areas of this soil are that the soil material in some bodies is either more acid or more alkaline than in typical areas, and a few bodies in the western part have some gravel on the surface. The latter areas are shown on the soil map with gravel symbols. The variations are slightly less valuable than the typical areas.

Coloso silty clay loam.—Coloso silty clay loam occurs principally between Arecibo and Manatí.

This soil differs from Coloso clay in that it is more friable and lighter in texture. It is considered a more productive soil for sugarcane, the crop for which it is best suited. Nearly 100 percent of this soil is used for the production of sugarcane, which yields from 45 to 60 tons of gran cultura an acre in average years, when the land is fertilized with from 600 to 800 pounds of fertilizer to the acre. The average acre yield of primavera sugarcane is about 40 tons; first ratoons yield about 35 tons, and second ratoons about 30 tons. Ratoon crops require more fertilizer than primavera crops. B. H. 10 (12) is the variety of sugarcane most commonly planted on this soil.

Coloso clay loam.—Coloso clay loam is less heavy in all layers than is Coloso silty clay loam, but it is sufficiently heavy and plastic to prevent water from percolating rapidly through it; therefore it has a mottled gray and grayish-brown subsoil and substratum, showing lack of perfect aeration. This soil occurs in small areas throughout the river flood plains mainly from Arecibo to Manatí and it is used exclusively for the production of sugarcane.

Coloso clay loam is more easily cultivated than are the heavier textured soils of the Coloso series, therefore it can be cultivated sooner after a rain. The same varieties of fertilizer and the same cultural practices are used on this soil as on Coloso silty clay loam.

Coloso silt loam.—Coloso silt loam is one of the more extensive Coloso soils and is the best one for the production of sugarcane. It occurs throughout the river flood plains from Humacao to Aguada. It is very similar to the clay loam, but it is more friable, slightly less mottled, and better drained. In the western part of the island, near Central Coloso, this soil is alkaline, but near Fajardo it is slightly acid. This soil is nearly as easy to handle as is Toa silty clay loam, and it is nearly as productive. It responds to irrigation in nearly all places. In some places, especially east of San Juan, a nearly black layer occurs at a depth ranging from 20 to 36 inches, and below this is the normal subsoil of mottled gray and brown clay.

Sugarcane on this soil is usually planted in furrows, and there are very few drainage ditches. Sugarcane yields from 55 to 66 tons an acre of gran cultura under very favorable conditions; primavera yields from 35 to 45 tons; and ratoons yield from 25 to 30 tons. Some farmers ratoon the sugarcane for several years on this soil. The fertilizer commonly used is 400 pounds of 12–6–5 and 400 pounds of sulfate of ammonium. B. H. 10 (12) is the most common variety of sugarcane grown, although P. O. J. 2878 and F. C. 916 have given very good results. Nearly 100 percent of this soil is used for the production of sugarcane.

Coloso loam.—A few areas of Coloso loam occur along Río Grande de Arecibo. This soil has been derived from material washed from the granitic hills near Utuado, and it is more gritty than the heavier textured soils of this series. It resembles Toa loam in many respects, but it does not have perfect drainage and therefore has a mottled rust-brown and gray subsoil and substratum. As most areas of this soil have an uneven relief, they are not very desirable for the production of sugarcane.

Fortuna clay.—Fortuna clay is a very productive level alluvial soil similar in physical characteristics to Coloso clay, but it is more acid in reaction. It is derived from materials washed from the Catalina and associated red acid soils, and therefore it probably contains less

plant nutrients than does Coloso clay. Most areas of this soil are in the eastern part of the island.

In a cultivated field, Fortuna clay has a 10-inch brown or grayish-brown cloddy dense clay surface soil which contains some gray and rust-brown streaks in the lower part. The subsoil, to a depth of 30 inches, is mottled grayish-brown and gray plastic clay that generally is moist or wet. Below this layer and continuing to considerable depth is mottled gray and light-gray plastic clay that in many of the more poorly drained areas contains some streaks of blue or green clay. Except in places where lime has been applied, this soil is acid throughout.

This soil is more difficult to cultivate than the well-drained closely associated Estación soils, but it is more easily prepared for the planting of sugarcane than are the sticky plastic Camagüey and Moca soils. As the land is poorly drained, the grand-bank system of planting is more commonly used than the furrow method. The ditches generally are dug and cleaned by hand labor. This is rather expensive but not so expensive as making and maintaining ditches in the Camagüey and Moca soils.

Probably more than 96 percent of this soil is used for the production of sugarcane, and B. H. 10 (12) is the variety most commonly grown. It yields from 40 to 55 tons of gran cultura an acre when the land is properly ditched, fertilized, and limed. The primavera and ratoon yields are from 5 to 10 tons an acre less. In most areas B. H. 10 (12) outyields S. C. 12/4 by 2 or 3 tons an acre.

Fortuna clay, poorly drained phase.—The poorly drained phase of Fortuna clay consists of areas closely associated with the typical soil but so situated that the water table is near enough to the surface to affect seriously the use of the land. The lack of good aeration and drainage causes this soil to be mottled gray and grayish brown and streaked with rust-brown iron stains from the surface to a depth below 30 inches. In most places this material is underlain by somewhat blue or green wet plastic material of marine origin.

This poorly drained soil is heavy and intractable, and, owing to the high water table, numerous ditches and a high grand-bank checkerboard system of drainage are necessary for the production of sugarcane that will produce yields equal to those produced on Fortuna clay. On most farms the same varieties of sugarcane and fertilizers are used on this soil as are used on the typical soil.

The largest area of this soil is planted or is in the process of being planted to sugarcane. Malojillo grass occupies a larger proportion of this soil than it does of the typical soil.

Fortuna silty clay loam.—Fortuna silty clay loam occurs mainly in a few areas south of Naguabo and near Añasco. All the areas of this soil have profiles more or less typical of Fortuna clay, but their surface soils contain less clay and more silt. This soil is slightly more productive than Fortuna clay because it is not so heavy and therefore can be worked under a wider range of moisture content. It does not crack so deeply when dry as does the clay soil, and sugarcane roots are not seriously injured by the force of the contracting soil.

Nearly the entire area of this soil is used for the production of sugarcane, which yields from 45 to 55 tons of gran cultura to the acre when the land is limed, fertilized, and properly managed.

Fortuna clay loam.—Fortuna clay loam occurs in several widely scattered areas, the largest of which is near Fajardo. Areas occur near Naguabo.

The surface soil of Fortuna clay loam consists of an 8- or 10-inch layer of grayish-brown or dark-gray cloddy acid clay. This material grades into mottled gray, rust-brown, and light grayish-brown sharp-angular acid clay at a depth ranging from 30 to 34 inches. This material, in turn, grades into plastic sticky light-gray clay containing some streaks of blue or greenish blue.

This soil has more adequate natural drainage than the other soils of the Fortuna series, and therefore a large proportion of the sugarcane is planted in furrows. The soil has sufficient water-holding capacity to enable the plant roots to survive a longer dry period than the roots of plants on the associated well-drained Estación clay loam.

The agricultural utilization of this soil is nearly the same as that of Fortuna silty clay loam. Applications of lime and especially fertilizer increase the yields of sugarcane to a very marked extent.

Vega Baja clay.—Vega Baja clay is nearly identical in position, relief, and character of the surface soil with the Coloso soils, but it has a striking red, gray, and brown mottled subsoil, indicating that the Vega Baja soil is probably a thin coating of alluvial clay deposited on old coastal-plain material. Most areas of this soil occupy an intermediate position between areas of the Sabana Seca and the Coloso soils.

In most places the 8- to 12-inch surface soil consists of mottled grayish-brown and light-gray acid slightly granular clay which is plastic when wet and cloddy, dense, and hard when dry. This layer rests on mottled red, gray, and yellowish-brown strongly acid plastic sticky clay which continues to considerable depth with very little change in texture or consistence. The variegated colors change, not only with depth but also from place to place. Some areas contain little or no red, and others have very few yellowish-brown streaks.

Vega Baja clay occupies less than 200 acres. Most of it lies between Arecibo and Vega Baja. Sugarcane and malojillo grass occupy about equal acreages. The areas in grass do not require drainage, but all areas planted to sugarcane require an extensive system of ditches, in order to drain off the excess water. When the land is properly drained, fertilized, and limed, crop yields are equally as good as those obtained on Coloso clay.

Vega Baja silty clay.—Vega Baja silty clay is the most extensive soil of the Vega Baja series. It occurs in a number of widely separated parts of the humid sections, where it occupies bordering or intergrade areas between the alluvial soils and the coastal-plain soils. It lies slightly above normal overflow, but during exceptionally high water it is flooded.

The surface soil to a depth of 8 or 10 inches is friable light-brown or grayish-brown granular acid silty clay or silty clay loam. This layer changes abruptly to a plastic medium-compact mottled yellowish-brown, gray, and red silty clay or clay subsoil, which continues to considerable depth and becomes slightly more definitely mottled and more acid with depth.

Vega Baja silty clay has slightly better natural drainage than Vega Baja clay. It is not so productive as the clay, however, because the subsoil is more compact and the plant roots cannot penetrate it so

readily for a supply of plant nutrients and moisture as they can the wet subsoil of Vega Baja clay.

Nearly all of the area of this soil is used for the production of sugarcane, which yields from 35 to 45 tons of gran cultura to the acre. The land is fertilized every year with from 400 to 500 pounds to the acre of 12–6–5 and about 500 pounds of ammonium sulfate as a second application. The principal varieties of sugarcane grown are B. H. 10 (12), P. O. J. 2878, and F. C. 916.

As mapped, Vega Baja silty clay includes numerous variations from the typical profile just described. Some areas occupy definite terrace positions and are much better drained than the typical areas, although they have the same general soil characteristics. Areas associated with the Estación soils have a deeper and browner surface soil than the typical areas. In some places the mottled subsoil lacks the red color. The texture of the surface soil also varies from place to place, ranging from silt loam to silty clay, the silty clay predominating.

Martín Peña clay.—Martín Peña clay is characterized by a nearly black plastic acid clay surface soil about 8 or 10 inches thick, that is very difficult to cultivate, and when it becomes dry large cracks are formed. The subsoil consists of mottled brown, yellowish-brown, and gray compact plastic acid clay, which gradually changes to the substratum at a depth ranging from 30 to 40 inches. The substratum is similar to the subsoil, but it is less heavy and not so compact.

This soil occupies low positions intermediate between the soils of the coastal lowlands and the river flood plains. It is influenced by a high water table that keeps the compact subsoil wet for considerable periods during the year, thereby enabling the plant roots to penetrate to greater depths than would be possible were the subsoil dry.

Areas of this soil include a number of variations in soil characteristics. In places, especially west of Dorado, the surface soil is nearly black and is underlain by a brightly mottled red and gray plastic stiff subsoil, which gradually changes with depth to rust-brown material. In other places, especially near Central San Vincente, the surface soil is black heavy plastic clay, which is underlain by a gray heavy stiff very acid clay subsoil.

This soil has practically no natural surface drainage, and owing to the compact plastic subsoil and substratum internal drainage is restricted. Deep extensive ditches are necessary in order to carry off the excess surface water. In many areas the soil is saturated with water for several days after a heavy rain.

The main variety of sugarcane grown on this soil is B. H. 10 (12). Unless the season is unusually wet, sugarcane, the principal crop, produces much higher yields than on the associated Sabana Seca clay. Sugarcane is planted in grand banks, but the system of ditching in few places is so effective as in areas of Coloso clay. In many places this soil is preferred for malojillo grass rather than for sugarcane.

Martín Peña sandy clay loam.—The outstanding differences between Martín Peña sandy clay loam and Martín Peña clay are the texture and color of the surface soil. The sandy clay loam has a grayish-brown or dark grayish-brown acid medium-plastic sandy clay loam surface soil that ranges from 6 to 16 inches in thickness, depending on the amount of alluvial material that has been deposited on the original very plastic compact mottled red, brown, and grayish-brown acid coastal-plain material.

This soil is used for the production of both malojillo grass and sugarcane. The acre yield of sugarcane is not so large as on Martín Peña clay, as the sandy clay loam is less fertile and very acid. Malojillo grass grows equally as well as on the clay.

This soil occurs throughout areas of the coastal plain from San Juan to Arecibo.

Talante clay.—Talante clay bears the same resemblance to Viví clay as Coloso clay does to Toa silty clay. Talante clay occurs in irregular-shaped long narrow ribbonlike strips near the streams in the eastern part of the island. In cultivated fields, the 6- to 8-inch surface soil is cloddy acid light-gray or light grayish-brown heavy clay that is plastic when wet. It is underlain by grayish-yellow or grayish-brown medium-plastic clay that contains some rust-brown stains and iron concretions. This layer continues to a depth of 20 inches. The substratum is mottled gray and rust-brown plastic sticky clay.

Water penetrates this soil better than it does the Josefa, Maunabo, and Yabucoa soils, but the movement of water is much more restricted than in the Viví soils. Drainage is necessary for the successful production of sugarcane, the crop that is grown on nearly 100 percent of the land. The sugarcane is planted in shallow grand banks, and, when the land is fertilized with from 400 to 600 pounds of 12–6–5 an acre and about 400 pounds of ammonium sulfate, gran cultura sugarcane yields from 40 to 50 tons an acre.

Talante silty clay loam.—Areas of poorly drained alluvial material similar to Talante clay but having a lighter textured surface soil are mapped as Talante silty clay loam. These two soils are so similar in characteristics that the boundary lines between them are drawn arbitrarily.

Talante silty clay loam is slightly more productive than the clay, and it is easier to cultivate. The variation in yield from year to year on the two soils is very similar. Neither soil is so productive as the Coloso or Fortuna soils, even under equally good management.

Talante clay loam.—Talante clay loam occurs in nearly level poorly drained areas near the streams in the eastern part of the island. The soil is derived from materials washed from the quartz diorite hills.

This soil has a medium-thick gray acid cloddy clay loam surface soil underlain by a poorly drained mottled gray and rust-brown acid clay or clay loam subsoil that becomes more gray and bluish gray with depth.

Nearly all of this soil is planted to sugarcane or is in the process of being planted to that crop. Yields range from 40 to 50 tons to the acre when the land is well managed and fertilized. Sugarcane roots can penetrate to moisture during dry periods, and for this reason the land is more productive than the well-drained Viví clay loam.

As the soil is low in fertility, it should respond to applications of lime and to fertilizers high in nitrogen and phosphorus.

Talante loam.—Talante loam is the most widely distributed soil of the Talante series. It occurs along granite-influenced stream courses near Patillas, Yabucoa, and Humacao. In places it occupies positions that are overflowed only during periods of very high water.

This soil has an 8- or 10-inch friable somewhat granular brown loam surface soil, which is underlain by a 10- to 14-inch layer of grayish-brown and rust-brown mottled acid or slightly acid clay loam that is fairly friable when dry but plastic when wet. Below this layer the

material gradually changes to bluish-black plastic wet clay, indicating constant saturation by water.

Talante loam requires drainage, but in most areas sugarcane is planted in furrows. Nearly all of this soil is used for the production of sugarcane, which yields fairly well when the land is properly fertilized and cultivated.

Talante sandy loam.—Talante sandy loam is an intermediate soil between Talante loam and Viví sandy loam and, therefore, has some characteristics of both. It has the gritty feel and the general appearance on the surface of Viví sandy loam, but the mottled gray and rust-brown subsoil is like Talante loam.

This soil is less productive than Talante loam, and it requires considerable fertilizer to maintain even relatively low fertility as compared with that of the Coloso and Aguirre soils.

Talante fine gravel.—Talante fine gravel represents a soil condition rather than a soil type. It occurs only on level alluvial land adjacent to the soils of the upland, especially the Teja soils. Run-off water has washed sand, gravel, and some small round rocks over the surface of this soil, resulting in a mixture of sand and gravel with much heavy-textured material ranging from heavy silt to clay. The subsoil is mottled gray and rust brown, and it ranges in texture from sandy loam to clay.

This soil occupies a very small total area. The land is used either for the production of sugarcane or malojillo grass, depending on the use of the adjacent alluvial soils. Some areas are fairly productive, and others are low in productivity.

Irurena clay loam.—Irurena clay loam occurs on level river flood plains in the eastern and southeastern parts of the island. It is derived from material washed from the coarse-grained granitic hills of the uplands and therefore is more gritty and less fertile than the Coloso and Fortuna soils, which are derived from tuffaceous materials.

This soil is characterized by a brown friable slightly granular acid clay loam surface soil about 10 inches thick that contains numerous small black iron concretions. The subsoil, to a depth of 20 or 24 inches, is brownish-gray or yellowish-brown acid heavy but not compact clay containing light-gray and rust-brown streaks. This layer is underlain by a deep substratum of gray plastic heavy clay that has many pockets and narrow beds of sandy material throughout its entire depth. The quantity of sandy material increases with depth.

Nearly the entire area of this soil is used for the production of sugarcane, which yields from 40 to 55 tons of gran cultura an acre when the land is properly fertilized and limed. B. H. 10 (12) is the variety of sugarcane most commonly grown. This land is imperfectly drained, but, as most areas occur where the average annual rainfall does not exceed 75 inches, numerous extensive drainage ditches are not necessary. The most common practice is to plant the sugarcane in modified grand banks and maintain a few large ditches to drain away the excess water after heavy rains. The sugarcane roots penetrate to the moisture-laden layers, and, because of this moisture supply, yields are higher than they would be, were the soil well-drained.

As mapped, Irurena clay loam includes several variations from the typical profile described. In a few places narrow irregular streaks of sandy material occur very near the surface. These cause a droughty condition during dry years and greatly reduce the yields of crops.

Few of the sandy strips are more than 15 feet wide, but they may extend several hundred yards in length. In a few places the surface soil and subsoil have a slight red tinge, but this does not seem to affect the utilization of the land. A few areas have a clay surface soil, but they are so small that they are included with the Irurena soil rather than differentiated as a separate soil type.

Irurena loam.—Irurena loam is closely associated with Irurena clay loam, and the two soils are similar in all soil characteristics except texture of the surface soil. The loam, because of its more sandy texture, is more gritty, less fertile, and slightly better drained than Irurena clay loam. It requires more fertilizer and more water, in order to produce the same yield of sugarcane as that obtained on the clay loam.

Nearly the entire area of this soil is used for the production of sugarcane, which is planted in furrows and fertilized with from 800 to 1,000 pounds of fertilizer for each crop of cane. Liming and irrigation of the land would increase the production on this soil during most years.

Yabucoa clay.—Yabucoa clay occurs in Valle de Yabucoa along the river flood plains. It differs from Irurena clay loam in that it has a light-colored surface soil, is heavier in texture, and is more poorly drained.

Yabucoa clay has an 8- or 10-inch surface soil of gray or light grayish-brown cloddy acid clay that becomes plastic and darker when wet.

FIGURE 127.—Cutting sugarcane on a field of Yabucoa clay. Often the cane to be used for seed is sacked. In many fields, as soon as the cane is cut, oxen feed on the green leaves for a day or two.

Cortando caña en un campo de Yabucoa arcilloso. A menudo la caña que se va a usar para semilla es ensacada. En muchos campos tan pronto como se corta la caña se meten los bueyes a comer las hojas verdes por un día o dos.

The subsoil to a depth of 20 inches is light-gray plastic clay containing some mottlings of rust-brown iron stains. The substratum to a depth of more than 50 inches is mottled gray and bluish-gray plastic clay. Throughout areas of this soil small pockets and narrow beds of sandy material may be present within any of the soil layers.

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Nearly the entire area of this soil is now planted to sugarcane (fig. 127), which yields from 30 to 45 tons to the acre. Almost all of the sugarcane grown on this soil in Valle de Yabucoa is planted in grand banks. Near Humacao most of the sugarcane is planted in shallow banks.

Small areas of this soil near streams have considerable gravel and small stones on the surface, but these have little influence on land use or productivity.

Yabucoa clay loam.—Associated with Yabucoa clay are several areas of Yabucoa clay loam. These two soils differ in soil texture and in ease of cultivation. The clay loam is preferred by most farmers. Nearly the entire area of this soil is planted to B. H. 10 (12) sugarcane, which yields from 38 to 50 tons an acre when the land is properly fertilized and cultivated.

Yabucoa loam.—A few acres of Yabucoa loam occur along the Río Ingenio north and northeast of Yabucoa. This soil is lighter in texture than Yabucoa clay loam, the soil it most closely resembles. All the land is planted to sugarcane in small grand banks.

Josefa clay.—Josefa clay is very closely associated with Yabucoa clay, but it differs from that soil in that it is more poorly drained and therefore has a more mottled gray and bluish-gray color from the surface to considerable depth. It occurs near Yabucoa and Humacao.

This soil is characterized by an 8-inch light-gray acid clay surface soil containing rust-brown and yellowish-brown streaks. When dry the material in this layer is cloddy and dense, but when wet it is plastic and readily becomes puddled under cultivation. The subsoil to a depth of 20 inches is mottled gray, light-gray, and rust-brown acid plastic wet clay. Below a depth of 20 inches the soil material gradually becomes more poorly drained, and therefore it is less well aerated and has a mottled green, blue, and gray color.

Josefa clay is very difficult to cultivate and plow, as it must be worked at the proper moisture condition. If the land is too dry the plow turns over large dense clods, and if the ground is too wet the plastic surface soil flows together and develops an undesirable puddled condition.

This soil requires many drainage ditches in addition to those necessary for the deep grand-bank plantings. If the land is properly drained, fertilized, cultivated, and planted to the B. H. 10 (12) variety of sugarcane, yields ranging from 35 to 45 tons an acre of gran cultura may be expected.

The tractability and productivity of this soil can be improved by applications of lime and organic matter.

Josefa clay loam.—Josefa clay loam differs from Josefa clay in that it is lighter in texture in all layers, is more easily worked, and is slightly more productive. Nearly the entire area is planted to sugarcane, which yields from 30 to 50 tons an acre, depending on the season. Ordinarily, this soil produces better during medium-dry years than during excessively wet years. The same varieties of sugarcane and the same fertilizers that are used for Josefa clay are profitable on this soil.

Maunabo clay.—Maunabo clay is associated with Josefa clay and other poorly drained soils on the level alluvial river flood plains near Yabucoa and Humacao. The Maunabo soil is derived from granitic

material that has been washed from the Pandura, Cayaguá, and related soils.

This soil has a brown or dark grayish-brown acid plastic clay surface soil ranging from 6 to 10 inches in thickness. It is underlain by mottled blue and light-gray plastic acid clay that is streaked with yellowish-brown or rust-brown stains. This material gradually changes to plastic sticky wet blue clay, which continues to a considerable depth. The water table is at a depth ranging from 10 to 20 inches below the surface.

Sugarcane is the most important crop grown on this soil, and the yields are similar to those produced on Josefa clay. Rice is planted on a few areas, but the results indicate that, under present conditions, this crop cannot compete economically with sugarcane.

Maunabo silty clay loam.—Maunabo silty clay loam occupies a few small areas in Valle de Yabucoa. It is associated with Maunabo clay, and the land use of the two soils is similar. This soil is less heavy in the surface soil and therefore is not so difficult to cultivate as is the clay soil.

Maunabo clay loam.—Maunabo clay loam is a slightly more desirable soil than either Maunabo clay or Maunabo silty clay loam. Owing to the smaller content of clay in the surface soil, the land is easier to cultivate and to ditch. Nearly the entire area is planted to the B. H. 10 (12) variety of sugarcane, which yields from 40 to 55 tons to the acre when the land is fertilized and properly managed. The water table is at a depth ranging from 20 to 24 inches below the surface, and for this reason the land is more productive than the nearby well-drained Viví soils along the riverbanks.

Maunabo loam.—Most areas of Maunabo loam are associated with sandy-textured areas of the Josefa, Yabucoa, and Irurena soils in the nearly level river flood plains along the larger streams in the eastern part of the island.

This soil is derived from material washed from the coarse-grained granite hills of the upland, and therefore it is gritty, light in color, and low in fertility. It has been leached to a great extent, owing to the heavy precipitation within the area of its occurrence. It requires a larger quantity of fertilizer in order to produce as high yields as those obtained on soils, such as the Coloso, derived from materials washed from tuffaceous materials.

This soil is so similar to Yabucoa loam that the boundaries between areas of the two soils are drawn arbitrarily.

Vayas clay.—Vayas clay is very closely associated with San Antón clay and occupies the more poorly drained level areas along the river flood plains in the semiarid south-coast section. The two soils differ, owing to the influence the high water table has had on the soil characteristics of Vayas clay. One of the main differences is the poorer aeration and consequent poorer oxidation in the Vayas soil, which causes a mottled gray or rust-brown and yellowish-brown layer beginning at a depth of about 30 inches (the average upper limit of the level of the water table) and continuing to considerable depths. A larger proportion of Vayas clay than of San Antón clay is affected with salts. Areas having more than 0.2 percent of salts in the topmost foot of soil are used only for pasture and are valued at about $60 an acre, whereas nonalkali areas are valued at prices ranging from $400 to $600 an acre.

Vayas silty clay loam.—Vayas silty clay loam differs from San Antón silty clay loam in that it has a high water table. It is, therefore, mottled with gray, rust brown, and yellowish brown at a depth ranging from 30 to 40 inches. It differs from Vayas clay in having a slightly more friable surface soil and in being less difficult to work.

Nearly 100 percent of this soil that is unaffected with salts is used for the production of sugarcane, which yields from 70 to 75 tons of gran cultura to the acre when the land is fertilized. This soil is not so productive as is San Antón silty clay loam, except during very dry years when irrigation water is not sufficient to water properly the San Antón soils.

Vayas silt loam.—Areas of Vayas silt loam that are not affected with harmful quantities of salts are very productive and yield from 70 to 90 tons of sugarcane to an acre.

This soil is similar to San Antón silt loam, but it has a water table from 30 to 40 inches below the surface and therefore is more difficult to drain and irrigate. Nearly all of the sugarcane is planted in furrows and is irrigated with from 8- to 10-acre feet of water for a gran cultura crop.

Vayas loam.—Vayas loam is very similar to San Antón loam, but it is more poorly drained and therefore has a more mottled subsoil, is more difficult to irrigate, and is not so desirable agriculturally. When irrigated and fertilized, however, it is more productive than Toa loam.

Aguirre clay.—Aguirre clay is the most important and most extensive soil of the Aguirre series. It occupies areas that are transitional in character between the soils of the well-drained river flood plains or alluvial fans and the poorly drained soils of the coastal lowlands. Most of the areas are fairly near the coast near Central Aguirre and Valle de Lajas, but a few small bodies are adjacent to the limestone hills along Río Guajataca and near Central Coloso.

In a cultivated field Aguirre clay has a 10- or 12-inch very dark grayish-brown or nearly black plastic clay surface soil underlain by mottled grayish-brown and gray plastic sticky clay that continues to a depth ranging from 30 to 36 inches. The upper part of the substratum is mottled gray, rust-brown, and yellowish-brown medium-plastic wet silty clay that in places contains some medium-sized gravel. At a depth ranging from 5 to 6 feet is the substratum of bluish-gray plastic sticky wet clay. This layer continues to considerable depths and has characteristics of estuarine deposits. Nearly all of the layers in the profile contain free lime both in disseminated form and in concretions. A few areas near Arroyo, where the average annual rainfall exceeds 60 inches do not have free lime in the surface soil.

Many areas of this soil contain sufficient salts, chiefly sodium carbonate, to limit the vegetal growth to halophytic plants, such as junquillo and verdolaga rosada (see fig. 129, p. 417). All areas that contain less than 0.2 percent of salts within the first 4 feet of soil are used exclusively for the production of sugarcane. The best drained areas that receive some irrigation are producing from 40 to 60 tons of gran cultura sugarcane to the acre.

In places this soil contains too much lime in the surface soil for the best production of sugarcane without the use of special fertilizers. This soil is high in phosphorus and potash but seemingly low in nitrogen, as fertilizers high in nitrogen give good returns.

The land is difficult to plow and cultivate, as when wet it is plastic and sticky, and when dry it is hard and cloddy.

Aguirre silt loam.—Aguirre silt loam occupies a few small areas east of Central Aguirre. This soil differs from Aguirre clay in that it is less heavy in the surface soil and therefore is more easy to cultivate and hence more desirable. Nearly all of it is used for the production of sugarcane, which yields as well as on Aguirre clay.

Guánica clay.—Guánica clay is similar to Aguirre clay, but it is more poorly drained and therefore is less well aerated and oxidized. It occupies lower positions than does Aguirre clay, and it is more difficult to drain and to irrigate. The largest areas of Guánica clay occupy lagoonlike positions near Laguna de Guánica that have been filled with materials washed from the nearby hillsides, which consist of tuffaceous rock and limestone. Only a small proportion of these areas is irrigated, and the water is pumped from wells ranging in depth from 40 to 100 feet. Some of the water contains a fairly high content of salt, and if this system of irrigation is continued for many years without more adequate drainage or abandoning the well containing salt, the land will accumulate so much salt that the roots of sugarcane cannot thrive. Areas of this soil east of Central Aguirre are irrigated and drained, but many of the areas contain so much salt that only a halophytic type of vegetation can grow.

Guánica clay has many variations in soil characteristics within the area of its occurrence, but in an average area the surface soil to a depth of 10 or 12 inches is very heavy plastic but granular nearly black calcareous clay that contains some gray and rust-brown mottlings. The subsoil to a depth of about 14 inches is gray or grayish-brown plastic cohesive heavy calcareous clay mottled with bluish-gray and rust-brown splotches. The substratum is bluish-gray very sticky plastic wet clay. Water penetrates this soil slowly because of its heavy texture and plastic consistence. Roots penetrate the soil readily, as it is usually wet and therefore rather pliable.

This soil is fertile and fairly productive when properly managed. Malojillo grass occupies about 60 percent of its area and sugarcane the remainder. Unless the land is irrigated, the productivity depends to a very large extent on the yearly rainfall. An acre yield of 40 tons of gran cultura sugarcane is considered high on nonirrigated land, but in the irrigated areas yields ranging from 50 to 60 tons are not uncommon. If the land is irrigated, sugarcane is planted in grand banks, and there must be many drainage ditches. In dry-land farming the sugarcane is planted in furrows, as this method of planting enables the roots to maintain a more secure roothold during droughts. There are very few drainage ditches in this soil. The malojillo grass produced grows thick and rank, and it is very nutritious.

In places this soil has a somewhat purple color in both the surface soil and the subsoil. In other places the surface soil is very dark—nearly black—and is extremely heavy but not compact.

Areas of this soil shown on the soil map with swamp symbols are subject to flooding during rainy seasons and at times are under 2 or 3 feet of water. In its present condition, the land is adapted only to the growing of malojillo grass, sedges, and aromo trees, but if drained it would have similar value to the typical areas of Guánica clay. Most areas of soil having the characteristics of Guánica clay are very good for the production of rice and yautia.

SOILS OF THE COASTAL LOWLANDS

The soils of the coastal lowlands include the well-drained sandy soils that fringe the coast; the imperfectly and poorly drained mineral soils, such as old estuarine clays and silty clays; those soils that have alluvial deposits over sandy beach materials; and the poorly drained organic soils.

These soils with but few exceptions occur within 1½ miles of the coast, and with the exception of dune sand the relief is nearly level. The rainfall ranges from less than 25 inches along the dry southwestern coast to about 80 inches along the coast at Mayagüez.

According to their physical and chemical characteristics, the soils in this group may be divided into two divisions, each having marked differences in natural inherent productivity and crop use. One division includes the soils having friable subsoils, which are also well-drained sandy-textured soils adapted to such crops as coconuts, minor crops, guinea grass, and elephant grass. Certain ones are adapted to citrus fruits and pineapples. The other division includes the soils having a plastic or wet subsoil. These soils also are poorly drained, and most of them are heavy textured. When drained they are adapted to sugarcane and malojillo grass, but in their natural condition saltgrass, ferns, and mangrove thickets are the principal vegetation.

WELL-DRAINED SOILS OF THE COASTAL LOWLANDS

The well-drained soils of the coastal lowlands include the friable noncoherent well-drained sandy-textured soils adjacent to or near the beach. (See fig. 96.) They include soils of the Cataño and Aguadilla series, Palm Beach sand, coastal beach, dune sand, Meros sand, and Jaucas sand. The last two soil types occur in the dry southern-coast section, and the others occur along the northern, eastern, and western coasts.

These soils, even with plenty of fertilizer and proper management, are not adapted to the production of sugarcane, because of their physical and chemical characteristics, but the better parts are adapted to minor truck crops and citrus fruits. Pineapples grow very well on Aguadilla loamy sand and Aguadilla sandy loam. Coconuts grow on all soils of the group except dune sand. The principal native vegetation is uva de playa (seagrape) and other xerophytic plants.

These soils probably have been washed from the interior to the coast, reworked by the action of waves, and deposited at the water's edge. After centuries and centuries of such activity, certain areas are now at a considerable distance from the shore. The Cataño and Aguadilla soils consist mostly of materials that probably have been washed from limestone and tuffaceous rocks. They also include many small sea shells that were trapped during reworking by the waves. Coastal beach, Palm Beach sand, and Jaucas sand consist mostly of various-sized sea-shell fragments, coral, and only a small quantity of sand. These are the most recent soils, and they are only partly developed. Meros sand probably is derived from dark-colored igneous material washed from the Cordillera Central to the south coast and reworked and mixed with sea-shell fragments by waves from the Caribbean Sea. Dune sand consists of wind-worked Cataño sand on the north coast and wind-worked Meros sand on the south coast.

Cataño loamy sand.—Cataño loamy sand is characterized by its high content of small sea shells and grayish-brown sand in all layers. It occurs as a narrow strip paralleling the sea, a short distance inland. It has a 10- or 12-inch surface soil of grayish-brown or dark grayish-brown loose noncoherent loamy sand which is very alkaline in reaction. This layer is underlain by a lighter colored and lighter textured calcareous subsoil about 2 feet thick. The substratum, to a depth ranging from 10 to 15 feet, is loose friable sand.

The main commercial crop grown on this soil is coconuts, which yield from 120 to 200 nuts a palm during the course of a year. Other crops grown very successfully are sweetpotatoes, yuca, beans, and peanuts. These crops, as well as pigeonpeas, can be grown among the coconut palms. Citrus orchards planted on this soil do surprisingly well, considering the high alkalinity of the soil. Some orchards more than 15 years old still produce profitable yields. In a few places the water table is so high that it interferes with the maximum growth and production of the trees.

Cataño loamy sand, shallow phase.—Areas of Cataño loamy sand that have a lime-cemented layer within 30 inches of the surface are mapped as a shallow phase. This soil is characterized by a 10-inch grayish-brown or dark grayish-brown calcareous friable single-grained noncoherent loamy sand surface soil underlain by a light grayish-brown friable noncoherent calcareous sandy layer which continues to a depth ranging from 20 to 30 inches. This material rests on an indurated lime-cemented sandy layer that in many places ranges from 6 to 7 feet in thickness. The numerous open wells or holes dug in this soil for the purpose of obtaining a supply of water for the household show that the water table is immediately below the cemented layer. The water may rise in these holes to a level within a foot of the top of the hardpan layer.

This soil is not so desirable for the production of citrus fruits as is the typical soil, as the roots of trees cannot readily penetrate the cemented layer. The trees grow very well for the first few years, but when expansion of the roots is stopped by the hardpan, the growth of the tree also is stopped or is retarded considerably. The shallow-rooted truck crops do equally as well on this soil as on the typical soil.

Cataño sand.—Many of the areas of Cataño sand that are adjacent to the coast line occur as long narrow strips, few of them more than 1,000 feet wide. This soil has a grayish-brown or dark grayish-brown friable noncoherent single-grained sandy surface soil about 6 or 8 inches thick, underlain by a lighter colored and lighter textured friable calcareous subsoil. The substratum is loose noncoherent gray sand. In a few places, this soil has a lime-cemented layer below a depth of 4 feet. This soil, when cultivated, becomes darker, probably owing to the incorporation of organic matter. In general this soil has a more irregular surface than has Cataño loamy sand. Most of it is planted to coconut palms, which yield from 400 to 800 nuts to the acre every 2 or 3 months. In many places a small patch of sweetpotatoes, beans, or pigeonpeas grows near the thatched houses, which are very numerous on this soil. A very high percentage of the people living on this soil are Negroes, as they seem to withstand the excessive heat along the sandy coast much better than do the white-skinned people.

A few areas of this soil in the southwestern part of the island that have an excessive amount of gravel on the surface are less desirable than the typical areas.

Aguadilla sandy loam.—Aguadilla sandy loam occurs in level areas, inland from areas of Cataño loamy sand. The Aguadilla soil differs slightly from the Cataño soils in having a slightly acid or at least only neutral surface soil, whereas the Cataño soils, especially the sandy types, have a calcareous surface soil.

Aguadilla sandy loam is characterized by a light-brown loose sandy loam surface soil from 6 to 10 inches thick, underlain by brown or dark-brown loamy sand, which in many places extends to a depth of more than 3 feet. Below this layer is loose friable calcareous gray sand. This soil has very good underdrainage because it is open and friable. It is too sandy, however, for the profitable production of sugarcane but does produce good yields of coconuts, peanuts, and sweetpotatoes. It is a very good soil for almost all kinds of vegetables, cotton, and citrus fruits, although very little of these crops is grown at present. One cottonfield on this soil along the northwestern coast produced nearly 1,800 pounds of seed cotton to the acre without water or fertilizer. That, however, was an exceptionally good yield.

Aguadilla loamy sand.—Aguadilla loamy sand is similar to Aguadilla sandy loam, but it has a lighter textured surface soil and subsoil. The 8- or 10-inch brown or grayish-brown friable incoherent single-grain loamy sand surface soil is underlain by light-brown loose friable incoherent sand that gradually changes to calcareous gray sand at a depth ranging from 30 to 40 inches.

This soil is well drained, contains a fair amount of organic matter, and is easily cultivated. It responds to heavy applications of fertilizer and produces high yields of pineapples, minor crops, and citrus. It is considered slightly superior to Cataño loamy sand. Vegetables are grown on this soil near Loíza.

Aguadilla sand.—Aguadilla sand is similar to Cataño sand, but it is more acid and browner. It is characterized by a brown incoherent friable porous acid surface soil 6 or 10 inches thick, underlain by light-brown friable loose sand that continues to considerable depth. In most areas calcareous gray sand occurs at a depth ranging from 30 to 40 inches. This soil is used for the production of coconuts, guinea grass, and minor crops.

Palm Beach sand.—Palm Beach sand comprises the narrow strip of sandy material along the immediate coast line, that has been washed up and reworked, for the most part, by action of the waves. This soil is pale-yellow or grayish-yellow sand or medium sand, containing an abundance of light-gray, brown, and yellow sand grains and many sea shells, most of which are long and rod-shaped, about one-sixteenth inch in diameter and one-fourth inch long. There is very little difference between surface soil and subsoil in physical or chemical characteristics. This soil is only a few feet above sea level and slopes gently upward toward the interior.

Coconuts grow fairly well on this soil but do not produce so well as on the slightly heavier textured soils, such as the Cataño or Aguadilla. This soil is not extensive, and probably 50 percent of it is producing nearly valueless seagrapes.

To the west of the mouth of the Río Manatí is a deposit of dark-colored sand containing a high percentage of magnetite. This in-

cluded area is a little heavier and of better quality than most areas of this soil.

Coastal beach.—Coastal beach represents narrow strips of land that parallel the coast and are composed largely of a thick accumulation of finely ground sea shells mixed with a small percentage of sand. Most of the areas are devoid of vegetation or are producing a few coconuts. This soil is considered less valuable than Palm Beach sand.

Dune sand.—Dune sand is very similar to Cataño sand, but it occurs on rather high dunes adjacent to the sea. The sandy surface soil is constantly shifting (fig. 11) owing to wind action, and this feature combined with the salt spray from the ocean makes this type of land nonagricultural. Even coconut palms do not grow on it. A few cacti and seagrapes are the only noticeable vegetation. These dunes are distributed in broken lines extending parallel with the coast from Loíza to Punta Borinquen, west of Isabela. A few small areas on the south coast resemble Meros sand, except that they have a hummocky relief.

Meros sand.—The 12-inch surface soil of Meros sand consists of grayish-brown or olive-brown loose single-grain incoherent igneous sand intermixed with an abundance of small sea-shell fragments. This layer gradually changes to slightly lighter colored coarser sand, which continues to considerable depths. In many places the water table is at a depth of 30 inches and the water is brackish.

This soil occupies beaches along the southern coast, sand bars running out into the sea, and areas along the mouths of rivers, especially westward from the outlets. This is owing to the westward wave currents, which carry the coarser materials washed down from the mountains and redeposit them along the beach in diminishing quantities directly in proportion to the distance from the outlet of the river.

This soil is used for pasture, coconuts, and minor crops. A larger acreage, however, is in cacti and uva de playa (seagrape) than in commercial crops. Owing to the low rainfall in areas where this soil occurs and to the porous character of the soil, all crops produce low yields. The soil is low in organic matter because it has been reworked by the action of waves, and the finer materials and organic matter have been washed into the sea. In a few places east of Ponce and inland from the shore, the surface soil is as heavy as a loam, but such areas are so small that they are included with the sand. Sugarcane grows fairly well on the loamy part of this soil when sufficient water is available and from 600 to 800 pounds of fertilizer an acre is applied. Minor crops also do better on this part of the soil than on the average areas.

In places gravel is excessive on the surface, and these areas are shown on the map with gravel symbols. Most of these areas are used only for pasture, which grows much better than on the adjacent nongravelly alkali areas.

Jaucas sand.—Jaucas sand is a mixture of nearly white coral fragments, sea shells, and a small proportion of igneous sands, underlain at a slight depth by soft coral limestone. The land in general is level, but it is modified in places by very small hummocks.

This soil occurs in narrow intermittent strips adjacent to the sea, and more than 50 percent of the land is barren. The other 50 per-

cent is occupied about equally by coconut palms and a xerophytic type of vegetation. The coconut palms are not very productive. Many of the nuts are small, and the palms grow more slowly than on the Cataño soils, which receive more moisture. This soil in many places is only a few feet above sea level, and the roots of palms are within reach of ground water, but the palms do not seem to grow so well as in areas receiving more than 60 inches of average annual rainfall. In some places, sweetpotatoes, yuca, and pigeonpeas are grown among the palms, and these crops produce fairly well during favorable years.

IMPERFECTLY AND POORLY DRAINED MINERAL SOILS OF THE COASTAL LOWLANDS

The imperfectly and poorly drained mineral soils of the coastal lowlands include the poorly and imperfectly drained mineral soils occurring in flat areas, and they consist of lagoonal deposits of clays, silts, and sands; alluvial material underlain by sandy beach material; and imperfectly drained coastal sands.

Most of the soils derived from the old estuarine or lagoonal deposits are heavy in texture, very plastic, and sticky, and they require rather expensive artificial drainage for their best utilization. These soils have been washed from the hills of the interior and from the alluvial deposits, and they have settled out in quiet lagoons that were separated from the ocean by sand bars or dunes. During emergence, the soil was exposed and most of the lagoons were drained. At present no difference can be noted in humid areas between the soil that originally was washed from the coarse-grained granite hills and that washed from limestone or tuffaceous rock. The soils now are fine grained, sticky, acid, and plastic, and they have the same land use. The soil layers have little aeration or oxidation and, therefore, most of them are gray or bluish gray. Soils of this group in the semiarid and arid districts generally are calcareous.

The soils of this group include soils of the Piñones and Palmas Altas series in the humid areas and soils of the Ursula, Serrano, and Cintrona series in the arid sections. The Ursula and Piñones soils are the most poorly drained, followed by the Serrano, Palmas Altas, and Cintrona. These soils, in their natural condition, are under water several months each year and while in that condition can produce only mangrove trees and other halophytic types of vegetation. Where adequately drained and properly managed, however, they produce from fair to good yields of sugarcane, ranging from 35 to 45 tons of gran cultura an acre. The grand-bank system of planting sugarcane is used throughout all areas of these soils. Malojillo grass and rice would grow very well and, in places, would compete with sugarcane for profitable yields, but it is doubtful if any other crops will do well—at least any now grown on the island. Probably less than 50 percent of these soils is drained and used for cultivated crops.

The land use of the other soils in this group—those having alluvial material overlying coastal sands and the imperfectly drained coastal sands—is different from that of the soils derived from old lagoonal deposits. The more sandy soils include the soils of the Córcega series, the poorly drained phases of the Aguadilla and Cataño soils, and the saline phase of Meros sand. All these soils, except the Meros, occur in humid or subhumid sections. The Meros soil occurs in arid sec-

tions. Most of these soils are sandy or have considerable gritty sand grains throughout their profiles. When drained these soils are used for the production of minor crops, coconuts, and sugarcane. The sugarcane grows on the heavier textured soils, and the lighter textured soils are used for subsistence crops and coconuts. In their natural condition, saltgrasses are the prevalent vegetation.

The soils derived from estuarine clays will be described first, followed by the soils derived from alluvial material over sand, and last by the imperfectly drained coastal sands.

Piñones clay.—Piñones clay occurs in lagoonlike positions throughout the north-coast section. It is somewhat similar to Coloso clay, poorly drained phase, but it is under water during a greater proportion of the year and is, therefore, more poorly drained and consequently less desirable for agriculture. It is characterized by a very dark grayish-brown or black plastic dense clay surface soil that contains some gray streaks, indicating poor drainage. This layer is underlain, at a depth of about 12 inches, by dark-gray plastic sticky clay that is generally wet. The material in this layer gradually changes to greenish-blue plastic sticky clay that continues to a depth of several feet.

The water table occurs at a slight depth, and during wet seasons the land is under water. Good drainage is necessary for the production of sugarcane, and, even after drainage has been established, during excessively wet seasons the sugarcane may be drowned out or the fields may become too wet for planting of the crop. A large percentage of this land is in pasture, mostly of malojillo grass, which grows very well on this wet soil. Ditching is the main problem, and on it depends the agricultural value of the land.

As mapped, Piñones clay includes areas that do not have any artificial drainage, and the soil consists of black sticky ooze over gray plastic sticky marine-deposited clay that grades to bluish-green clay. Most of these included areas are in mangroves or saltgrass.

Piñones silty clay.—Piñones silty clay differs from Piñones clay in that it has a less heavy and less plastic surface soil. It is associated with Piñones clay on flat water-soaked estuarine deposits mainly from Loíza to Arecibo. It is characterized by an 8- to 12-inch gray or dark-gray plastic sticky acid silty clay surface soil that gradually changes to a grayish-black plastic sticky clay subsoil ranging from 1 to 2 feet in thickness. The subsoil is underlain by a greenish-blue plastic sticky wet substratum.

This soil, where adequately drained and properly managed and fertilized, produces from 40 to 45 tons of sugarcane to the acre. Undrained, it is used for pasture and the growing of mangroves for the making of charcoal.

Piñones sandy clay loam.—Piñones sandy clay loam has an 8-inch surface soil of dark grayish-brown medium plastic sandy clay loam or sandy clay, containing some fibrous decomposed vegetation. It is underlain by a 15- to 20-inch layer of greenish-gray plastic clay. The material in this layer gradually changes with depth to a dark-brown or black peaty muck deposit.

Most areas of this soil occur near muck deposits along the north coast and are occupied by a swamp vegetation. Very little if any of the land is now under cultivation. This soil is very similar to Piñones clay, peaty-subsoil phase.

Palmas Altas clay.—Palmas Altas clay is a soil of better quality than is Piñones clay. It has a gray or dark-gray plastic clay surface soil, about a foot thick, which becomes hard and dense when dry and breaks into angular fragments. This layer is underlain by a grayish-black or greenish-black plastic clay subsoil, 2 feet thick, which is saturated with water. The substratum is gray sticky wet clay.

This soil, if properly drained, is good for the production of sugarcane, yields of which range from 35 to 45 tons to the acre, provided the water table is kept below the majority of the sugarcane roots. Inasmuch as the level of the land is not more than a foot or two above sea level, drainage involves an expensive establishment of ditches, dikes, and pumps, and, unless these are properly installed, salt water may contaminate the soil. Most areas of this soil are in swamp grass, mangroves, and pasture.

This soil in general is alkaline or slightly salty. It occupies the edges of old lagoons and estuaries, where the water table is high and influences the development of the soil to a great extent. The soil layers have little aeration or oxidation, and, therefore, are generally gray or bluish gray.

A few acres of this soil have a conspicuous quantity of sand and gravel on the surface, but the presence of gravel does not seem to lower the productivity of the land.

Palmas Altas silty clay.—Palmas Altas silty clay is an inextensive soil. It occurs in small areas near Arecibo and Camuy.

This soil is somewhat similar to Coloso clay, poorly drained phase, but it is even more poorly drained and more acid. It is characterized by a 12-inch grayish-brown plastic dense clay surface soil containing more gray streaks, indicating poor drainage. This layer is underlain by grayish-black plastic sticky clay, which is generally water-soaked. This layer gradually changes to greenish-blue sticky clay, which continues to considerable depth. During wet seasons this soil is often under water. Good drainage is necessary for the production of sugarcane. Malojillo grass grows very well, and the yearly carrying capacity of the pasture is about four head of bullocks to an acre.

Ditching is the main problem with this soil, and on it depends the agricultural value of this land.

Palmas Altas silty clay loam.—Palmas Atlas silty clay loam also is an inextensive soil. It occupies a very small total area southeast of Humacao and near Yabucoa.

This soil differs from Palmas Altas silty clay in that it is less heavy in all layers and is slightly more easy to till. Nearly the entire area is planted to sugarcane under the grand-bank system. Sugarcane yields from 32 to 42 tons to the acre when the land is properly fertilized and managed.

It is necessary to keep the drainage system in good repair throughout the year, as sudden tropical downpours may cause considerable damage to large fields of sugarcane unless effective drainage systems are established.

Palmas Altas sandy clay loam.—Areas of Palmas Altas sandy clay loam represent soil conditions or soil complexes rather than a definite soil type. This soil, as mapped, does not have consistent texture of either the surface soil or subsoil. The 6- or 8-inch surface soil consists of silts, sands, gravel, and clays mixed in different proportions

within short distances. The soil reaction is neutral in some places and strongly acid in others. In most places the subsoil is light-gray sandy loam or clay loam mottled more or less with yellowish-brown clay. In some places stratification of clay and sands occurs, and in other places the soil material is mostly silty clay. The substratum, below a depth of 4 feet, in many places consists of greenish-brown or greenish-gray wet sands.

This soil occupies low depressions and is subject to frequent floodings. The water table generally is within a few inches of the surface. Some selected areas are drained and used for the production of sugarcane, which yields from 30 to 40 tons an acre when the land is properly managed. Most of the areas are forested with mangroves or are producing a tall dense grass that is of little value.

Areas of this soil near Fajardo Playa are decidedly gravelly and sandy in all layers. The high water table in these areas prevents the use of the land for truck crops, which should grow very well were the land adequately drained.

Palmas Altas loam.—Palmas Altas loam occupies slightly more than 400 acres along the coast near Yabucoa and Humacao. It is characterized by a gray or grayish-brown plastic acid loam surface soil 8 or 10 inches thick, underlain by gray plastic sandy clay or sandy clay loam streaked with yellowish-brown stains. The material in this layer changes but little with depth. In places, yellowish-brown sand layers occur irregularly throughout the profile.

This soil, when properly drained and planted to sugarcane, is fairly productive. The grand-bank method of planting is used.

Ursula clay.—Ursula clay consists of calcareous gray marine clays that are salty and have a high water table. Most areas are forested with mangroves or support other halophytic vegetation.

This soil, in a typical mangrove forest area, has a 2-inch layer of gray silty plastic sticky ooze underlain by pale greenish-gray sticky plastic clay more than a foot thick, which contains numerous soft mangrove roots in various stages of decay. The material in this layer gradually changes to pale-gray sticky plastic clay or silty clay containing many fragments of shells. In many places the color of this layer is blue green at a depth ranging from 4 to 5 feet. The material in all layers is very calcareous. In most areas, it contains more than 0.3 percent of salt, mostly sodium chloride. The water table is within a few inches of the surface, and many areas are flooded during high tides.

The expense of draining this soil and washing out the salt would be very high, and it is doubtful whether the returns would warrant such an expenditure, as sugarcane, the crop best adapted to this soil, would be affected with chlorosis unless treated with sulfur or some other chemical or large quantities of manure.

Cintrona clay.—Cintrona clay bears the same relationship to Serrano clay in the dry sections that Palmas Altas clay does to Piñones clay in the humid sections.

The surface soil of Cintrona clay, in a cultivated field of sugarcane, consists of a 10-inch layer of light grayish-brown somewhat granular plastic clay. It is underlain by gray or nearly white plastic clay which ranges in thickness from a few inches to over a foot and is extremely high in content of lime carbonate and sea shells. Below this layer is gray or bluish-gray wet plastic clay, which continues to a

considerable depth. The material in all layers effervesces with dilute hydrochloric acid, indicating the presence of carbonate of lime. In places, this soil has an accumulation of salt, owing to the high water table, which is within 3 feet of the surface.

In areas where soluble salts have not accumulated to a harmful extent and the land has been properly drained, ditched, and banked, sugarcane produces fairly well, as the roots are subirrigated by the high water table and irrigation is needed only during certain periods of growth. This soil, when drained, has good physical characteristics for a high production of sugarcane, but, owing to the very high lime content, especially in the gray subsoil, yields of sugarcane are greatly reduced because of the numerous chlorotic spots, from 5 to 100 yards in diameter, that occur in the planted fields. In some ratoon sugarcane fields more than one-half of the area is affected by chlorosis. Some gran cultura fields have nearly one-sixth of their area affected. Primavera fields are affected the least. The chlorosis affects both the leaves and the stalks. Chlorotic conditions are more noticeable during dry seasons and when the gray calcareous subsoil is turned up and exposed during plowing. Sulfur, manure, and residue from the cane would probably benefit these chlorotic spots.

Cintrona silty clay loam.—Cintrona silty clay loam is more valuable for agricultural use than is Cintrona clay, because the surface soil is not so heavy and intractable and the land is more easily cultivated.

In drained areas, Cintrona silty clay loam has a 10- or 12-inch surface soil of brown, or grayish-brown mottled with gray, coarsely granular silty clay loam, which is friable when dry but plastic when wet. The subsoil is similar to the surface soil in texture, consistence, and structure, but it is much lighter gray and has a higher content of lime carbonate. This layer is underlain, at a depth of 2 feet, by gray clay, which breaks, when dry, into small prismatic clods and shows evidence of imperfect drainage by the numerous rusty-brown iron stains and angular iron concretions, as well as the gray color, indicating lack of aeration. The material in all layers is calcareous, and the water table occurs at a depth of about 3 feet.

Drainage, fertilization, irrigation, and careful management are necessary for high yields on this soil. Probably over 50 percent of this soil is producing sugarcane; the remainder is charged with alkali, and only pasture grass and halophytic vegetation grow on it.

This is the most extensive soil of the Cintrona series. It occurs in rather large intermittent areas near the coast mainly from Ponce to Salinas.

Cintrona loam.—Cintrona loam is closely associated with Cintrona silty clay loam. It occurs in level or flat positions throughout areas derived from lagoonal clay overlain by alluvial deposits, in the dry areas near the coast from Ponce to Salinas also in small areas west of Guánica.

This soil has a 10- or 12-inch surface soil of grayish-brown plastic loam or clay loam. It is underlain by a gray plastic clay subsoil, which continues to a depth of 2 feet. Beneath this, the soil material gradually changes to bluish-gray plastic sticky clay, which continues to a great depth. The material in this layer contains many rusty-colored stains and iron and lime concretions. The material in all layers is

calcareous, and more than one-half of the land is undrained and produces only alkali-tolerant vegetation.

This soil, when drained, fertilized, and irrigated, produces from 35 to 45 tons to the acre of gran cultura sugarcane. B. H. 10 (12) is the best variety grown.

Serrano clay.—Serrano clay occurs in slightly lower positions than Cintrona clay, and it is, therefore, more poorly drained, lighter in color, has a higher proportion of its area impregnated with salt, and is much less valuable.

There is very little change in the color or texture of the soil from the surface to a depth greater than that reached by most plant roots. The soil consists of gray highly calcareous plastic sticky clay containing many rusty-brown clay mottlings, and in its natural condition the water table is at or near the surface. Most areas have about 0.3 percent of salt in the topmost foot of soil, and there are many barren areas that have a white incrustation of salt one-fourth of an inch thick. Such areas have more than 3.0 percent of salt in the topmost foot of soil.

Most areas of this soil are forested with mangroves and support other halophytic vegetation. A few small areas have been drained and planted to sugarcane, but the expense of drainage is very high because of the high water table. Many areas of this soil planted to sugarcane are badly affected with lime chlorosis, especially those in ratoon crops. The principal varieties of sugarcane grown are B. H. 10 (12) and C. O. 281. The average acre yield is about 45 tons. The fertilizer used is a 12–8–4 mixture, together with two applications of ammonium sulfate.

This soil occurs as long narrow strips adjacent to or slightly inland from the south coast.

Serrano sandy clay loam.—The 8- or 10-inch surface soil of Serrano sandy clay loam is gray plastic calcareous sandy clay loam. It is underlain by a grayish-yellow, mottled in places with rusty brown, calcareous fine sandy loam subsoil, which continues to a depth of about 2 feet. The substratum, to a depth ranging from 30 to more than 40 inches, is mottled light-gray and blue-gray sticky plastic sandy clay, which is usually wet, as the water table, even in drained areas, is at a depth ranging from 20 to 30 inches. Included with this soil are some areas in which the texture of the subsoil and substratum ranges from sand to heavy clay.

This is not an extensive soil. It occurs throughout a narrow strip along the south coast.

Open or tile ditches and, in places, pumps are necessary to drain this land before agricultural crops can be grown. The expense involved is so great that only a small proportion of the land is in cultivated crops. Sugarcane is the best crop for this land, and the yields produced, fertilizer used, and varieties grown are about the same as those for Serrano clay.

Serrano loam.—Serrano loam occupies a few areas east of Ponce, near the coast. It occurs in low nearly flat areas that are sometimes inundated with high tidal waters.

This soil has a gray plastic calcareous loam or fine sandy clay loam surface soil about 12 inches thick, underlain by a light-gray sandy

loam or loam plastic sticky subsoil about a foot thick. The substratum is blue-gray sandy loam or clay, containing some shells and much lime carbonate.

Much of this soil is swampy and salty, but in places where the land is drained the water table generally is below a depth of 20 inches. The drained areas are used for the production of minor crops and sugarcane.

Serrano sandy loam.—Serrano sandy loam is the least extensive Serrano soil in Puerto Rico. It differs from Serrano sandy clay loam in that it is sandier in all layers and when drained is better adapted to the production of minor crops than are the heavy-textured Serrano soils, but it is not so productive for sugarcane. This soil is associated with Meros sand. One of the larger areas is near the mouth of the Quebrada Cayures, west of Salinas.

Córcega sandy clay.—Córcega sandy clay is a heavy-textured soil of the coastal lowlands, so situated that it has been influenced both by the underlying beach sand and by the heavy alluvial deposits. It occupies level areas inland from the sea, where the former coastal sands are covered with material washed from the limestone and tuffaceous shale hills. The largest areas are near Añasco and Aguadilla.

In a cultivated field, this soil has a dark grayish-brown or brown medium-plastic, but granular when dry, sandy clay surface soil, ranging from 8 to 12 inches in thickness, underlain by a grayish-brown plastic somewhat stiff sandy clay loam subsoil about a foot thick. The substratum consists of yellowish-gray friable sand or sandy loam. Included with this soil in mapping are several areas having a clay or clay loam surface soil. The surface soil of Córcega sandy clay is alkaline, and the subsoil is calcareous. In most places the water table is between 30 and 36 inches from the surface, which is high enough for subirrigation.

Nearly the entire area of this soil is used for the production of sugarcane, which yields from 40 to 55 tons of gran cultura and 30 tons in ratoon crops to the acre when the land is properly fertilized and managed. The grand-bank system is the most common method of planting used on areas of this soil.

Córcega sandy clay, poorly drained phase.—Areas of Córcega sandy clay that have a water table within 18 inches of the surface are mapped as a poorly drained phase. This soil is readily identified by a mixture of gray calcareous sand on the numerous crab-hole mounds that are conspicuous only in places where the water table is high. This soil is not so productive for sugarcane, the most profitable crop grown, as is the typical soil.

Córcega sandy loam.—Córcega sandy loam occurs only on the low level land near the coast in the western part, near Añasco.

The 6- or 8-inch surface soil is brown medium-firm but friable neutral sandy loam or loam, which gradually changes to the grayish-brown friable sandy loam subsoil, which is about 14 inches thick. The substratum consists of gray calcareous friable incoherent sand, which is usually wet, owing to the high water table.

This soil is sometimes used for the production of sugarcane, but yields are low. The land is much better adapted to minor crops, peanuts, and coconuts.

Córcega sandy loam, poorly drained phase.—Areas of Córcega sandy loam that occur in such low positions that the water table is within 10 inches of the surface are mapped as a poorly drained phase. This soil has the same physical characteristics as has the typical soil, but, owing to the high water table, it is used only for the production of grass, which grows very well. The poorly drained soil is associated with the typical soil in the vicinity of Añasco.

Aguadilla sandy loam, poorly drained phase.—Areas of Aguadilla sandy loam that are covered with water for a sufficient length of time to affect their land use are mapped as a poorly drained phase. The physical characteristics of this soil and the typical soil are almost identical, but, owing to the proximity to the sea, the water table under the poorly drained soil is at or near the surface. Therefore, the only vegetation growing on this land is saltgrass or halophytic plants. This soil has a much lower value than the typical soil. It occurs only along the eastern coast.

Aguadilla loamy sand, poorly drained phase.—Aguadilla loamy sand, poorly drained phase, differs from Aguadilla sandy loam, poorly drained phase, with which it is associated in the eastern part of the island, in that it has a lighter textured surface soil and subsoil. The difference in texture does not have any effect on the growth of the saltgrass and halophytic vegetation, and one soil is considered equally as good as the other. This soil also occurs near Cataño. It is used only for pasture.

Cataño loamy sand, poorly drained phase.—Areas of Cataño loamy sand occurring so close to lagoons or the ocean and at such a low elevation that the water table is within 18 inches of the surface are mapped as a poorly drained phase. This soil occurs in only a few small areas, principally near Humacao. Most of it is wasteland, and it is used to some extent for pasture. In a few places, sufficient salt has accumulated on the surface to kill all except the salt-resistant grasses and weeds.

Cataño sand, poorly drained phase.—Areas of Cataño sand, poorly drained phase, differ from Cataño loamy sand, poorly drained phase, in that they have a sandier textured surface soil. This soil occurs chiefly near San Juan, associated with Cataño sand.

Tidal water or high ground water deposits salt throughout this soil, and therefore most areas are not cultivated and produce only saltgrass.

Meros sand, saline phase.—Areas of Meros sand that occur in positions so low that the water table is at or near the surface, causing the soil to become impregnated with salt, are mapped as a saline phase. This soil occupies numerous small areas along the south coast.

This soil is characterized by a brown calcareous incoherent fine sand or sand surface soil about 6 inches thick, underlain by light-olive calcareous coherent sand, which gradually changes at a depth of about 18 inches to slightly darker soil containing many gray and

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greenish-blue splotches. In most places the water table is within a foot of the surface, and, in places, brackish or salt water covers the lower small pockets.

The land is used only for pasture. The water table is too high for the production of coconuts. Areas that have an excessive quantity of surface gravel, shown on the map with gravel symbols, are not so desirable as the typical soil.

POORLY DRAINED ORGANIC SOILS OF THE COASTAL LOWLANDS

The poorly drained organic soils of the coastal lowlands occupy low flat areas adjacent to or only a few miles inland from the coast. The soils in this group are so closely associated and so similar in characteristics that there is no sharp line of demarcation between any two adjoining soil types. In their natural condition these soils are water-soaked or under water many months of the year. They support a growth of mangroves or similar trees, reeds, and sedges. Most areas are impregnated with salty or brackish water.

The organic soils differ from the mineral soils in that they contain more than 30 percent of organic matter, are fibrous, spongy, and generally black or reddish brown, and have a foul odor below a depth of 2 feet. They have been formed for the most part from the remains of plants and to only a slight extent from decomposed mineral matter.

The soils included in this group are Tiburones muck; Saladar muck; Saladar muck, shallow phase; peat; peat, shallow phase; Piñones clay, peaty-subsoil phase; and Reparada clay.

Attempts have been made repeatedly to drain areas of these soils for the purpose of planting sugarcane or malojillo grass. Thus far, less than 2,000 acres are in cultivated crops, chiefly sugarcane, which grows rank and dense and produces a high yield of cane but a low yield of sucrose. Only a few crops are adapted to these soils, owing to their internal characteristics as well as to their external environments, such as the fluctuation of a brackish water table. Malojillo grass grows well on the drained or partly drained nonsalty areas, but it is doubtful whether the quality of the grass is as nutritious as that produced on the river flood plains. Were the organic soils adequately drained and properly fertilized, many kinds of truck crops could be produced on them.

The value of these soils for agricultural crops depends to a very great extent on the cost of adequate drainage. Some areas can be drained adequately during most years, but exceptionally wet years or even an extraordinary heavy rain may cause inundation and drown the crop. Some areas are nearly impossible to drain as they occupy positions below the level of low tide.

Most of the uncultivated parts of these soils are mangrove swamps, with cattails, ferns, and sedges growing on certain areas, such as areas of Tiburones muck. Buried trees are conspicuous in the drainage ditches in many of the drained areas.

Most of these soils are firm enough for a person to walk across without danger of sinking much above the ankles, or, in some places,

the knees. Even the small peat-bottom lagoons can be waded if the water is not deep. In cutting the mangrove trees for making charcoal, the peons walk across any of the water-covered swamps.

The making of charcoal is the most important enterprise on all the undrained areas of these soils. The many species of mangrove trees grow densely and rapidly, regardless of the content of salt in the soil or water. A common practice is to cut over the land at intervals ranging from 5 to 10 years. The wood produced is less than 3 inches in diameter, but it makes good charcoal. Mangrove swampland is valued at prices ranging from $5 to $20 an acre. When adequately drained, ditched, and banked, its value is increased nearly tenfold. The land settles considerably the first 3 to 5 years after it is drained and cultivated, but during the course of the survey no area was observed that had been burned over, as is common in many areas of organic soils, especially peat areas, in the United States.

The organic soils of the coastal lowlands range from slightly to strongly acid and require from 1 to 1½ tons of lime to the acre every 3 to 5 years, as well as from 600 to 800 pounds of fertilizer, in order to produce from 30 to 40 tons of sugarcane an acre. These soils require much potash.

Tiburones muck.—Areas of Tiburones muck, if not drained and cultivated, are covered with water most of the year. The most noticeable types of vegetation are ferns, sedges, grass, and cattails. When dry, drained, and cultivated, the surface soil to a depth of 10 inches is nearly black granular loose mealy more or less mineralized slightly acid friable muck, but when wet it is black plastic sticky muck. This layer is underlain by black stringy fibrous tule peat consisting of partly decomposed stems and fibers. It is slightly acid in reaction and salty. The material in this layer continues below a depth of 6 feet. Here and there throughout this material, however, there is a band of somewhat blue or green plastic smooth clay about 6 or 8 inches thick, which is acid and slightly salty. Below the clay are other layers of tule peat.

Attempts have been made to drain most of this type of muck, and at different times sugarcane has been planted, but its production has proved a failure except on the most favorable areas. At present, only a little over 150 acres of this land are planted to sugarcane. Sugarcane will grow vigorously for several months, or until the water table creeps up around the lower roots, drowning them and causing the cane to stop growing or to die. Alkali salts, mostly sodium chloride, also are a limiting factor in some areas.

The fertilizer most commonly used on this soil is 800 pounds of 10–8–6 and 200 pounds of sulfate of ammonia as the second application. The sugarcane varieties grown are B. H. 10 (12), P. O. J. 2725, and P. O. J. 2878. About twice as much B. H. 10 (12) is grown as of any other variety. Yields range from 30 to 45 tons of gran cultura an acre and from 20 to 30 tons of ratoon crops. The sucrose content is low, generally from 9 to 11 percent. Among other crops grown is malojillo grass for pasture, which yields very well but during wet seasons does not contain much nourishment.

The largest areas of Tiburones muck are those in Caño Tiburones and north of Central Canóvanas.

Saladar muck.—Most areas of Saladar muck are covered with water most of the time and support growing or cut-over mangrove forests. (See fig. 96.) This type of muck consists of dark grayish-brown or black smooth salty strongly acid silty clay material and partly decomposed organic matter in which there is a mass of living and dead plant roots. In places there is a black slimy ooze covering the surface to a depth of 2 or 3 inches. At a depth of about 10 inches is brown smooth-textured organic matter containing layers of raw or partly decayed plant remains. In places the material, from the surface down, is black or very dark grayish-brown smooth fine-textured silt interspersed with plant remains in various stages of decomposition. This soil has no agricultural value, except for the gathering of wood for charcoal.

Saladar muck occurs throughout the northern, eastern, and western coasts. Nearly all of the areas contain harmful quantities of salt brought in by the tide.

Saladar muck, shallow phase.—The shallow phase of Saladar muck represents a condition rather than a consistent development of a soil profile. It is always very wet, usually under water, and generally contains considerable salt. In places it may be composed mostly of peat and muck, with some mineral soil, and in other places it may be mostly mineral soil with some muck or peat. In some areas there is a layer of peat about 12 inches thick underlain by white acid sand. The agriculture practiced on this soil is very similar to that on Piñones clay, peaty-subsoil phase. The shallow phase of Saladar muck is associated with the typical soil from Carolina to Arecibo.

Peat.—Areas of peat are not readily differentiated agriculturally from those of Tiburones muck. Most of the peat areas are in mangrove swamps, but in the cultivated areas, crop yields differ little from those obtained on Tiburones muck. The largest cultivated areas of peat are near Loíza. These areas are not very salty and have very good artificial drainage.

Peat in general has a reddish-brown coarsely fibrous surface material about 10 inches thick. In mangrove thickets it contains many somewhat yellow fine rootlets of mangroves, and in most places the topmost inch or two of the surface layer is black sticky tidal ooze. Below the surface layer is fine-fibered brown peat, which generally continues below a depth of 4 feet and rests on grayish-black or bluish-black plastic sticky clay containing many gray fine rootlets. Peat is acid in all layers and very salty unless drained. Areas far from the coast are less salty than those near the coast.

Sugarcane is as productive on peat as on Tiburones muck. It yields from 35 to 45 tons of gran cultura an acre, when the land is limed and fertilized, provided the water table is not within 1 or 1½ feet of the surface for long periods, or even for short periods when the cane is young.

Peat occurs on many of the small mangrove islands along the south coast as well as throughout areas below sea level near the coast.

Peat, shallow phase.—Areas of peat land that have either sand or clay deposits within 18 inches of the surface are mapped as peat, shallow phase. Most of this land occurs east from San Juan and is in mangrove forests. It is not very extensive and is nonagricultural at present. It is acid and is as salty as the typical peat areas. Most areas are water-soaked throughout the year.

Piñones clay, peaty-subsoil phase.—Piñones clay, peaty-subsoil phase, consists of alluvial deposits over peat and muck. It occurs in low-lying level positions and is associated with, but occurs on slightly higher elevations than, areas of peat and muck.

This soil is characterized by a mottled dark-gray, gray, and brown plastic dense clay surface soil about a foot thick. Beneath this layer is light-gray or greenish-gray plastic water-soaked clay resting on organic soil materials at a depth ranging from 20 to 30 inches. The material in all layers is acid, the acidity increasing with depth. The topmost foot of soil is similar to the corresponding layer of Piñones clay, but the lower parts are similar to Saladar muck. Some areas have only a 4- to 6-inch layer of clay over the organic material.

The largest areas of this soil are near Central Coloso, Loíza, and Humacao. Most areas are under water several months each year, and therefore, grass, such as malojillo, is the best crop to grow. With adequate drainage, sugarcane grows fairly well, but a very small proportion of the land has good artificial drainage. Some areas are seriously affected with salt.

Sinkholes.—In areas underlain by limestone, especially on the north side, there are thousands of sinkholes where water drains away into underground streams. Some of the sinkholes are filled with water during a part or all of each year. The larger of these are outlined on the map, and hundreds of very small ones are indicated by a special symbol.

Reparada clay.—Reparada clay is very similar to Piñones clay, peaty-subsoil phase, but it occurs in areas where the climate is dry, and therefore it is more alkaline in reaction.

It is characterized in most places by a 12- to 18-inch dark-gray plastic clay or silty clay surface soil that is underlain by fibrous peat, which is decayed sufficiently in a few places to be nearly black in the upper part. The peaty subsoil extends to a depth ranging from 30 inches to several feet. In a few places, such as near Haciendas Reparada and Ursula, the land has been ditched and banked and is producing sugarcane about equal in quantity and quality with that grown on the Serrano soils.

Some of the soil included in mapping with Reparada clay lacks the clay surface layer. In some places the soil lies so near sea level that it is flooded most of the time with sea water and is covered with various species of mangroves. Such areas are used only for the gathering of wood to make into charcoal. All the areas that are producing mangroves are very salty. Along the southwestern coast many small areas of peat are included with this soil.

AGROLOGÍA (SUELOS Y COSECHAS)[25]

Agrología, la ciencia que estudia los suelos y cosechas, ofrece información valiosa a todo agricultor eficiente que se interesa en obtener el máximo beneficio de sus tierras a costo bajo de producción. La experiencia del pasado suplementada con un estudio científico cuidadoso de agronomía y suelos, dentro de límites razonables, indica si la tierra se adapta a una cosecha determinada. Condiciones desfavorables de clima, ataques de plagas é insectos, y los cambios económicos inherentes a las cosechas, influyen siempre en modificar las prácticas agrícolas corrientes de una región.

Para poder determinar la adaptabilidad de una cosecha a un terreno es de prima importancia conocer los requisitos fisiológicos de la cosecha. El sistema de raíces de las plantas cultivadas en Puerto Rico es extremadamente variable en cuanto a profundidad de penetración en el suelo, poder de resistencia a la sequía y habilidad para extenderse dentro del suelo y absorber suficiente alimento. No es posible esperar que la caña de azúcar que tiene un sistema profundo de raíces, que requiere mucha agua y abono, produzca buenos rendimientos en suelos poco profundos, relativamente impermeables, pobres en fertilidad y que reciban poca cantidad de agua. Sin embargo, podemos esperar buenos rendimientos, si la caña se siembra en suelos friables y profundos que tengan un alto contenido de materia orgánica, que estén libres de sales perjudiciales o de subsuelos cascajosos, y que reciban más de 70 pulgadas de agua de lluvia o riego. Ahora bien, una cosecha, como la del tabaco, que tiene una sistema superficial de raíces, crece favorablemente en un suelo poco profundo. La yerba de guinea produce mejor forraje en suelos de buen drenaje y en los suelos de regiones áridas. No pasa así con el malojillo que crece mucho mejor en suelos que permanecen saturados de humedad por un período considerable del año. Algunas cosechas se adaptan a varios suelos, pero por lo general la producción máxima se obtiene solamente en algunos tipos de suelos.

Puerto Rico, debido a las fluctuaciones de lluvia, a su vegetación natural, al relieve accidentado, y a las variaciones de edad en los suelos y de composición química en las rocas, tiene un número de tipos de suelos relativamente grande para el tamaño pequeño de la isla. El mapa de suelos representa un total de 352 tipos y fases y 6 terrenos misceláneos. Cada uno de ellos se discute detalladamente en la sección escrita en inglés intitulada "Soils and Crops" (Suelos y Cosechas). El capítulo intitulado, Agrología, abarca solamente una discusión breve de los varios tipos de suelos agrupados en series.

Visto desde un aeroplano a gran altura, Puerto Rico tiene muchas fajas distintas de relieve del terreno; cada una es característica de una zona agrícola determinada. Partiendo desde la costa hacia el interior estos cambios de relieve sirven para dividir los suelos en seis grupos como sigue:

1. Suelos de la Altura.
2. Suelos de las Llanuras Interiores.
3. Suelos Abancalados y de Aluvión en Abanico.

[25] Traducido por Juan A. Bonnet, Jefe Sección de Suelos, Estación Experimental Agrícola de la Universidad de Puerto Rico, Río Piedras, P. R.

4. Suelos de las Llanuras Costaneras.
5. Suelos de los Valles de Aluvión.
6. Suelos de los Bajos Costaneros.

El primer grupo se extiende hasta el segundo, que conecta en algunos sitios, con el tercero. Este último está íntimamente asociado con el cuarto. El quinto grupo está entremezclado con el sexto.

SUELOS DE LA ALTURA

Los suelos de la altura ocupan casi tanto espacio como el área de todos los otros suelos de Puerto Rico. Incluyen un área tan grande en el centro que podemos llamarlos el espinazo de la isla. Los suelos de este grupo tienen una variación amplia en características. Varían de negros a casi blancos, de ricos a pobres, de ácidos a alcalinos, de textura lómica arenosa fina hasta arcillosa, de poco profundos a profundos y de jóvenes a viejos. El clima es de árido a húmedo y la elevación varía desde alturas bajas hasta más de 4,000 pies sobre el nivel del mar. La mayor parte del café, chinas, guineos y vainilla y la mayor parte del tabaco y frutos menores, lo mismo que la yerba de pastoreo, se producen en los suelos de este grupo. Estos suelos han sido puestos en tres subdivisiones de acuerdo con la profundidad de la roca descompuesta. También existe una correlación entre los suelos de cada subdivisión y el uso de la tierra y adaptación de la cosecha.

La subdivisión más importante es probablemente la de los suelos profundos de la altura que incluye 21 tipos y fases de las series Catalina, Cialitos, Los Guineos, Alonso, Malaya, Jayuya, y Nipe. Estos suelos ocurren en toda la extensión de la parte húmeda del interior de la isla y sus elevaciones varían de 100 a cerca de 3,000 pies sobre el nivel del mar. Todos estos suelos, con la excepción de la serie Jayuya, han sido derivados de rocas volcánicas e ígneas de grano fino que han sido descompuestas rápidamente bajo el clima caliente y húmedo tropical produciendo suelos que tienen un alto contenido de arcilla permeable y que son bajos en limo y arena. Todos son de color rojo o rojopurpúreo. Los suelos de la superficie son ácidos, friables y fáciles de preparar para la siembra. Los subsuelos son usualmente muy ácidos y pesados, pero son permeables y tienen drenaje adecuado. La profundidad del subsuelo y substrato aumenta con el aumento de precipitación pluvial anual y según modera la inclinación de la pendiente.

Muchos de los suelos de esta subdivisión ocurren en colinas escarpadas. También toda la región está disectada por numerosos canales que tienen la forma de una V. Muchos de los sitios con pendientes escarpadas están sembrados de cosechas que requieren desyerbos. Si no se manejan bien, mucho del material superficial se pierde por efecto de la erosión, aún en las pendientes de 10 a 15 por ciento que por lo general no son muy afectadas por la erosión. Después de fuertes lluvias, las corrientes que corren por las pendientes cultivadas se cargan pronto de arcilla roja y púrpura. La formación del suelo es rápida y en muchos sitios balancea las pérdidas de erosión. En climas húmedos y calientes la vegetación crece rápidamente y ayuda a reducir la erosión a un mínimum, excepto en las pendientes que están cultivadas impropiamente. Las aguas que corren sobre la mayor parte de las

fincas de Puerto Rico siguen un camino corto y escarpado antes de que bañen las gargantas cubiertas de vegetación o los arroyos de fondo rocoso.

Estos suelos, con excepción de las series Jayuya y Nipe, tienen algunas rocas grandes sobre la superficie y a través del perfil. Las áreas que llevan en el mapa el símbolo indicado para piedras tienen mayor cantidad de rocas.

Estos suelos se adaptan físicamente a muchas cosechas, pero debido a la deficiencia en substancias químicas como cal, fósforo y magnesio; al relieve quebrado, elevación alta y situación lejos de pueblos y caminos, las cosechas más importantes que se siembran son café, chinas, guineos y árboles de madera. Las citrosas, la piña y la caña de azúcar son cosechas importantes que se siembran en las áreas de relieve moderado y en los sitios bajos y adyacentes a los caminos.

Los suelos de la serie Alonso son los mejores en productividad natural; les siguen en orden, los de las series Malaya, Catalina, Jayuya, Cialitos, Los Guineos, y en último lugar los de la serie Nipe que son excesivamente bajos en productividad. Mientras más escarpado es el relieve menos productivos y menos deseables son estos suelos. Generalmente, bajo condiciones iguales, la producción es cerca de cuatro veces mayor en las pendientes cóncavas que en las convexas. El cafeto que produce 100 libras de café en las pendientes convexas producirá de 400 á 600 libras en las cóncavas. Los suelos de las pendientes cóncavas son más altos en materia orgánica y tienen más espesor en la capa superficial que los de las convexas; esto se debe a la acumulación gradual de tierra y vegetación residual que viene de arriba. También las pendientes cóncavas están mejor protegidas del viento y tienen mayor contenido de humedad que las convexas.

Las fases de estos tipos de suelos que ocurren en pendientes lisas son más deseables y se adaptan a mayor variación de cosechas. Las áreas de topografía plana, excepto si se abonan fuertemente, son generalmente menos productivas que las de topografía ondulante moderada porque los suelos han sido más lavados, son más ácidos y tienen drenaje interno algo más pobre. Las pendientes coluviales son generalmente las áreas más deseables de todos los tipos y fases, especialmente si ocurren bajo las áreas de la serie Múcara y los suelos alcalinos relacionados. La incorporación del material fresco que trae la erosión de los sitios más altos de las pendientes aumenta la productividad de los suelos coluviales.

La segunda subdivisión más importante de los suelos de la altura son los que tienen subsuelos medio profundos. Aquí se incluyen las tierras comprendidas en las colinas de las regiones húmedas y semihúmedas donde la roca madre se encuentra a profundidades de 1 a 2 pies de la superficie.

El tabaco y las cosechas de subsistencia se adaptan mejor a estos suelos, que la caña de azúcar y las citrosas. Esto se debe a que el relieve escarpado y la capa delgada de tierra favorece las cosechas que tienen un sistema de raíces poco profundo. En los sitios mejores que están cerca de los caminos principales y de las centrales azucareras se siembra alguna caña de azúcar. Casi todo el tabaco de mejor calidad, la mayor parte del arroz secano, y probablemente el 60 por ciento de todas las cosechas de subsistencia como habichuelas, maíz, gandules y batatas, se producen en estos suelos. Bajo las condiciones

actuales el éxito o fracaso de miles de personas depende del uso y la productividad de estos suelos; pues un gran número de los habitantes de la zona rural se sostienen, total o parcialmente, de lo que se cosecha en ellos.

El valor de estos suelos depende del grado de pendiente, de la cantidad de suelo superficial que se ha perdido por erosión, y en parte, del número de años que han sido cultivados sin abonarse.

La administración juiciosa de las fincas comprendidas en estos suelos requiere atención adecuada en abonamiento, prevención de la erosión y diversificación de cosechas. Es también de provecho tener suficiente ganado y aves de corral.

Las 16 series de esta subdivisión incluyen 39 tipos y fases. Las series Colinas, Soller y Tanamá, se derivan de la caliza Terciaria; la serie Plata se deriva de la capa inferior de la arcilla Terciaria; las series Daguao, Múcara, Juncos, Sabana y Naranjito, se derivan principalmente de tobas macizas, esquistos de tobas, y otras rocas volcánicas; la serie Río Piedras se deriva de esquistos; y las series Pandura, Cayaguá, Ciales, Utuado, Teja, y Vieques, se derivan de rocas ígneas, especialmente de granito.

Los suelos de esta subdivisión que se derivan de la misma roca o de roca similar se discuten juntos.

Los tipos de suelos clasificados como Colinas arcilloso lómico, Colinas pedregoso lómico, Colinas fino arenoso lómico, y Soller arcilloso se derivan de piedra caliza blanda; son calcáreos a una profundidad de 20 pulgadas y el suelo superficial de algunas colinas es también calcáreo. Los suelos mejores de este grupo, cuando están adyacentes a los caminos principales, se dedican a caña de azúcar. El tipo Soller arcilloso es el mejor para caña; le siguen las áreas mejores del tipo, Colinas arcilloso lómico. El rendimiento en estos tipos de topografía ondulante y escarpada es de 35 a 40 toneladas de caña gran cultura por acre y de 20 a 35 en los retoños. Frecuentemente se cultivan seis retoños de caña en estos suelos. El contenido de sacarosa es generalmente alto; muy pocas de las cepas de caña echan mamones como sucede a las que crecen en aluviones húmedos. La variedad principal de caña que se siembra es S. C. 12/4; pero está siendo reemplazada rápidamente por la P. O. J. 2878 y la P. O. J. 2725 porque la S. C. 12/4 cuesta más cultivarla y es más susceptible al mosaico. La P. O. J. 2878 tiene un sistema superficial de raíces, pero cuando se siembra en estas arcillas plásticas pesadas y en los tipos lómico-arcillosos, no es fácil arrancarla de raíz, como cuando crece en el aluvión mojado. Como el suelo por lo general está seco, las yemas de la caña que están sobre el suelo, aún si el viento acuesta la cepa, no tienen humedad suficiente para germinar; si esto ocurre, ese crecimiento secundario de la caña produce pérdidas de sacarosa. La caña Uba se da bastante bien, pero no es recomendable sembrarla porque es dura para cortar y moler. La Mayagüez 28 promete en muchas de las colinas, resiste bien la sequía, produce buenas cepas, y como cierra temprano, reduce el número de cultivos que son necesarios para matar las malas yerbas. Estas tierras se abonan generalmente con una primera aplicación de 400 libras por acre del 12–6–8 y una segunda aplicación de 400 libras de sulfato amónico por acre.

Aunque la mayor extensión de estos suelos se dedica probablemente más a pastos que a caña de azúcar, debido al precio, la caña se considera

como el cultivo principal. La mayor parte de la tierra dedicada a pastos permanentes está cubierta con un colchón de yerba cerrillo de hoja fina mezclada con grama de hoja ancha. Casi todas las áreas están libres de malas yerbas. Para el pastoreo se necesitan 1½ a 3 acres de terreno por cabeza por año. La entrada anual es de $6 á $12 por acre si la tierra se pastorea todo el año como corrientemente se hace. La tierra dedicada a pastos se vende entre $25 y $40 el acre. En zonas lluviosas similares, los suelos derivados de piedra caliza producen yerba mejor y de más nutrimento que los suelos derivados de esquistos y tobas.

Las principales cosechas de subsistencia que se cultivan en estos suelos son: batatas, gandules, maíz, habichuelas y yautía. El promedio de producción por acre es como sigue: 800 a 1,200 libras de batatas, 300 a 600 libras de gandules, 10 fanegas de maíz, 350 a 450 libras de habichuelas y de 1,000 a 1,500 libras de yautía.

Cuando estos suelos se dedican a cosechas que requieren cultivo frecuente, la erosión del suelo superficial es mucho más que lo que parece al dueño de la finca. A pesar del cultivo continuo, estos suelos producen ahora rendimientos más altos, especialmente de caña de azúcar, que en años anteriores. Este aumento se debe al mejoramiento en las variedades de caña, en el cultivo y en el abonamiento. La erosión empieza en la parte alta del cerro y continúa gradualmente hacia abajo por la pendiente. La buena tierra negra de la superficie es lavada hacia abajo. Es verdad que por algún tiempo las pendientes producen mejores rendimientos, pero esto lo hacen a expensas de los sitios más altos cuya tierra ha sido lavada por la erosión. En algunos sitios de los cerros ya no queda tierra superficial, sólo queda un subsuelo de poco espesor a veces, y otras veces sólo queda la piedra caliza desnuda. La caña de azúcar que crece sobre estas colinas calcáreas es a veces afectada por clorosis, pero el daño ocasionado no es tanto como el que se observa en las regiones áridas. No es posible esperar que la caña que crece en estos sitios calcáreos, cubiertos de una delgada capa de suelo, produzca los rendimientos más altos que se obtienen en las laderas coluviales más bajas que tienen un suelo negro superficial de más de 8 pulgadas de espesor sobre un subsuelo pardo amarillento y plástico de espesor similar. Cuando se abonan las cosechas sembradas en estos cerros calizos la producción es buena; esto se debe a que la cal blanda es friable y permite la penetración profunda de las raíces. Estos suelos producen rendimientos aun mayores que las pendientes de las series Múcara y Río Piedras que han sido menos afectadas por la erosión. Si no se evita la erosión llegará el momento en que la tierra sólo servirá para pastos. Algunas de las pendientes más escarpadas del tipo Soller arcilloso, ya sólo sirven para pastos. Las tierras usadas para el pastoreo continuo han sido algo afectadas por la erosión, pero no tanto como las que se han dedicado a caña de azúcar; y estas últimas han sido menos afectadas que las sembradas con cosechas de subsistencia, especialmente gandules, habichuelas y maíz. La erosión de estos suelos se debe a que su consistencia plástica no permite absorber rápidamente el agua para ayudar a reducir la velocidad de la corriente fluvial superficial. La erosión puede evitarse sembrando al contorno y cosechando en fajas (strip cropping), es decir, sembrar entre predios de la cosecha principal, franjas intermedias de yerbas o plantas que sirvan de colchón para sostener la tierra.

Estos suelos tienen una topografía ondulante. Se encuentran en toda la parte noroeste de la isla desde la costa hasta una distancia de más de 8 millas hacia el interior. La elevación varía desde cero hasta 700 pies sobre el nivel del mar; la precipitación pluvial anual varía desde cerca de 50 pulgadas, próximo a Isabela, hasta más de 95 pulgadas, próximo a San Sebastián. Como estos suelos son jóvenes y contienen mucho carbonato calizo blando la lluvia tiene muy poco efecto en lavarlos; otros suelos que reciben de 70 a más de 90 pulgadas de lluvia anualmente pierden muchos nutrimentos por efecto del lavado. A mayor lluvia, más oscuros son, y más materia orgánica tienen. La calidad y clase de yerba cambia poco, pero en las áreas secas hay menor cantidad que en las húmedas.

Los canales de drenaje son cortos, indefinidos, y la mayoría de las veces conducen a canales subterráneos. Muy pocas corrientes fluviales cruzan estos suelos; el agua para uso doméstico es limitada, inadecuada, y muchas veces está lejos de las muchas casas construídas sobre los cerros. Parte del agua se recoge de la lluvia que cae sobre los tejados de zinc de las casas.

Los suelos de la serie Tanamá se derivan de caliza Terciaria medianamente dura; ésta se desintegra tan despacio que sólo produce una capa delgada de suelo color rojo, permeable y ácido. En esta subdivisión sólo se incluyen los tipos Tanamá pedrego-arcilloso, fase lisa, y Tanamá pedrego-arcilloso, fase coluvial. La mayor parte de estos suelos se dedican a fincas pequeñas cuyos propietarios siembran café, guineos, tabaco y cosechas de subsistencia. Los rendimientos son generalmente bajos. Una extensión considerable sirve sólo para bosques debido a la existencia de sumideros y a las rocas expuestas.

Los suelos de la serie Plata están íntimamente asociados con los de la serie Soller, pero son derivados de material más viejo, y en algunos sitios, tienen considerable cantidad de grava en todo el perfil. Alrededor del 60 por ciento de los suelos de la serie Plata están sembrados de yerba, 25 por ciento de caña de azúcar y el resto de frutos menores y café. Estos suelos son tan productivos como los de la serie Juncos.

Los suelos de las series Daguao, Múcara, Juncos, Sabana y Naranjito, están íntimamente relacionados. Se han derivado de material similar; tienen casi la misma profundidad hasta la roca descompuesta, y todos se adaptan a cosechas similares. Varían en color de negro a gris oscuro claro, y en acidez de alcalino a fuertemente ácidos. Empezando con los suelos de la serie Daguao que son los más alcalinos y oscuros, los suelos se tornan menos oscuros y más ácidos en el orden siguiente: Múcara, Juncos, Sabana y Naranjito. Los suelos de la serie Daguao son los que reciben menos lluvia, y los de la serie Naranjito los que reciben más. Por lo tanto, podemos decir generalmente que cuando el suelo recibe más agua se vuelve más ácido y más gris.

Estos suelos ocurren en la parte semi-húmeda de la isla, entre las zonas calizas del norte y el sur y al este de éstas. Las fases escarpadas de estos suelos se incluyen en el grupo de los suelos de la altura que tienen subsuelos poco profundos y se dedican principalmente a pastos, pero los tipos de suelos en esta subdivisión se usan extensamente para tabaco, cosechas de subsistencia y caña de azúcar. Si estos suelos están dentro de una milla de distancia de una carretera y a no más de 4 millas de una factoría azucarera, una gran parte del área se siembra más bien de caña, que de otras cosechas.

Si la tierra es propiedad de, o es administrada por las centrales, la caña produce de 25 a 35 toneladas por acre, porque se pone atención en desyerbarla, en abonarla, y en sembrar la variedad adecuada. Si la tierra es propiedad de, o es administrada por terratenientes pequeños, la producción de caña, raras veces es más de 20 toneladas por acre; a veces, baja hasta 12 toneladas por acre, porque los dueños no tienen capital suficiente para abonarla y atenderla adecuadamente. Las observaciones de campo indican que en las condiciones actuales, con el azúcar pagándose a 3 centavos libra, esta tierra debe producir más de 15 toneladas de caña por acre para dar beneficio. Estos suelos son poco profundos hasta la roca madre; no es posible, por lo tanto, esperar que las raíces de la caña puedan extenderse para buscar los nutrimentos y el agua que necesita la planta para producir un buen cosecho. Las raíces de la caña de azúcar no pueden penetrar las rocas como lo hacen las raíces de los árboles; por lo tanto, la caña sufre por falta de agua durante la sequía. En los suelos de la serie Juncos, y cerca de las faldas de las colinas que son ocupadas por otros suelos, la roca está más profunda y los rendimientos son más altos.

Como el tabaco y muchas cosechas de subsistencia se dan muy bien en los suelos poco profundos, una gran extensión de estos suelos se siembra de estas cosechas; la producción es medianamente regular, pero más alta que la obtenida en los suelos ácidos y rojos de la altura.

Una de las prácticas más notables en el cultivo de estas tierras, especialmente cuandro se siembra tabaco, es cavar zanjas estrechas y poco profundas a los lados de las colinas sin tomar en consideración lo escarpado de la pendiente. El fondo de muchas de las zanjas descansa sobre roca sólida, esto evita el efecto de la erosión barrancosa. Los arrastres que llegan a la zanja son llevados por las corrientes fluviales hacia el mar; si se tienen muchos cuadros pequeños de 20 a 30 pies, rodeados por zanjas, el agua no arrastra mucha tierra hacia la zanja. Estas zanjas reducen la erosión y ayudan a drenar la tierra, mejorando por lo tanto, las condiciones para el mejor crecimiento del tabaco.

Los suelos de la serie Río Piedras se derivan de rocas de origen volcánico, principalmente de esquistos. Ocurren en las laderas de las colinas y en las montañas. Las rocas se desintegran rápidamente bajo las condiciones tropicales y dan origen a suelos de textura arcillosa pesada. El tipo Río Piedras arcilloso tiene un suelo y subsuelo característico de arcilla pesada, plástica y ácida, cuyo color varía entre gris, amarillo y rojo. El suelo superficial es plástico; resbala cuando está húmedo y es duro y frágil cuando está seco. La roca madre se encuentra, en algunos sitios, a profundidades de cerca de 2 pies; pero no hay precisión en la línea de demarcación. Todo el perfil es ácido. La mayor parte de estos suelos ocurre en la vecindad de Río Piedras; algunas áreas están cerca de la Central Coloso y en Fajardo. Se adaptan mejor a caña de azúcar; producen de 25 a 35 toneladas de caña de gran cultura. En los años favorables, dos acres dedicados a pastos, sostienen una cabeza de ganado. Los rendimientos de todas las cosechas son bajos porque el suelo es pobre en materia orgánica, es extremadamente ácido y todo el suelo es plástico y pesado. El suelo es pobre en fósforo. Requiere administración muy juiciosa debido a su plasticidad, fertilidad pobre, sensibilidad al drenaje interior y susceptibilidad a la erosión.

Los suelos de las series Pandura, Cayaguá, Ciales, Utuado, Teja y Vieques, son derivados de material granítico; tienen por lo tanto,

muchas características similares. Son de colores claros, arenosos al tacto, están bien drenados, son medianamente profundos y susceptibles a la erosión laminosa; muchos son ácidos y de textura gruesa. Muchos de ellos son pobres en nutrimentos, especialmente en nitrógeno; pero se cultivan extensamente a no ser que sea imposible hacerlo debido a la presencia de numerosas rocas y peñones. El tabaco es la cosecha principal; le siguen en importancia y extensión, cosechas de subsistencia tales como habichuelas, maíz y batatas.

Estos suelos ocurren en colinas cuya elevación varía de 500 pies a más de 1,500 pies sobre el nivel del mar. La precipitación pluvial anual varía desde menos de 40 pulgadas en las tierras de Vieques a más de 90 pulgadas en algunas áreas de las series Pandura, Cayaguá, Ciales y Utuado. La serie Teja recibe un promedio de lluvia de cerca de 70 pulgadas al año.

La serie Cayaguá es la más productiva; le siguen las series Utuado, Ciales, Vieques, Pandura y Teja. Mientras más escarpado es el relieve el suelo es menos deseable y es más afectado por la erosión laminosa cuando se siembran cosechas que requieren desyerbos. Desde el punto de vista geológico, estos suelos son los más afectados de la isla por la erosión. Están completamente disectados por canales de drenaje, que en su mayor parte tienen la forma de una U, y que tienen en su fondo una capa profunda de arena gruesa y cascajo fino.

La calidad de agua que se encuentran en toda el área de estos suelos es buena pero la cantidad no es tan grande como la que hay en las áreas comparables de las series Catalina, Múcara y otras asociadas.

Los suelos poco profundos de la altura se dividen en 19 series que incluyen 37 tipos y fases y 1 terreno misceláneo. Su área total es probablemente mayor que la de cualquier otro grupo de suelos en la isla. Los suelos de esta subdivisión se encuentran en toda la altura de Puerto Rico. Son muy poco profundos y muy pedregosos. La roca madre se encuentra a profundidades menores de 18 pulgadas de la superficie.

Estos suelos varían mucho más en relieve y en precipitación pluvial recibida que otros suelos en la isla. El clima varía de árido a húmedo y el relieve de plano a quebrado. Debido a la rocosidad, a la poca profundidad, al relieve desfavorable, al clima seco, o a la combinación de una o más de estas características, las yerbas cubren de 60 a 65 por ciento del área, los árboles como el 15 por ciento, los matorrales como el 15 por ciento y las cosechas de subsistencia y el café soló de 5 a 10 por ciento.

En muchos de los países que están menos densamente poblados, se clasificarían probablemente muchos de los suelos de esta subdivisión como tierra quebrada pedregosa y se les daría poco o ningún valor agrícola. Puerto Rico está tan superpoblado que mucha gente se ve obligada a vivir en estas colinas quebradas y rocosas donde se dedican a la cría de pollos, cabros, lechones y ganado. En los años favorables, los predios pequeños de tierra mejor producen cosechas de subsistencia. Tanto el número de habitantes como el valor alto de la tierra ha obligado a clasificar estas tierras poco profundas con más cuidado que el que corrientemente se pone.

Este grupo incluye suelos de las series Colinas, Soller, Aguilita, Tanamá y Ensenada, derivados de caliza Terciaria; suelos de las series San Germán y Lajas, derivados de caliza Cretácea; suelos de las series Jácana, Descalabrado, Guayama, Daguao, Múcara,

Picacho y Naranjito, derivados de esquistos Cretáceos, tobas, y parte de rocas ígneas, especialmente andesíticas, suelos de las series Mariana y Yunes, derivados de esquistos y riolita; suelos de las series Juana Díaz derivados de piedra arenisca; suelos de la serie Vieques, derivados de granito; suelos de la serie Rosario, derivados de serpentina; y terrenos quebrado rocosos, derivados en su mayor parte de rocas ígneas duras.

Debido a la característica del suelo y al ambiente climatérico, las dos cosechas que se adaptan mejor a estos suelos son: árboles en las regiones húmedas, y yerbas en las regiones áridas, semi-áridas y semi-húmedas. El negocio mejor es el de ganado lechero, de carne, o para cruce. El valor del ganado es mayor que el de la madera que se corta de los árboles.

Muchos de los suelos producen una calidad excelente de yerba porque son jóvenes debido al relieve escarpado y a la poca profundidad, y porque no han sido tan lavados de sus bases y nutrimentos como los suelos viejos y profundos que ocurren en las áreas donde llueve mucho. También el material de suelo que está cerca de las raíces de las plantas se rejuvenece constantemente debido a la desintegración de la roca madre que está cerca de la superficie. Esta característica favorable del suelo, suplementada con un período de crecimiento casi continuo, hace que estos pastos sean superiores a muchos de los Estados Unidos. El pasto mejor se produce en las pendientes largas de inclinación moderada donde la lluvia es suficiente para el continuo crecimiento de la yerba, y no causa pérdidas de nutrimento debido al lavado del suelo.

Muy pocos, casi ninguno, de los agricultores, abonan los pastos. Las malas yerbas y matorrales molestan en algunos sitios y hay que cortarlos cada dos o tres años. Algunos pastos abandonados se cubren de malas yerbas y matorral en un término de cinco años. Las plagas que afectan más a los pastos son; el guayabo, que se extiende rápidamente en las áreas húmedas y semi-húmedas; la zarzarilla, arbusto que infesta los pastos de las regiones áridas; y el guayacán blanco o guayacanillo, mala yerba nociva que crece en los suelos poco profundos derivados de piedra caliza, cuyo polen causa irritación a los ojos del ganado. Muchos rancheros informan que el ganado que come la zarzarilla pierde el pelo como ocurre en Hawaii, en Santa Cruz y en muchas otras islas tropicales.

La yerba permanente más común de las áreas húmedas es la grama y el cerrillo. Yerba Yaraguá o de maleza, y yerba Guatemala, son las que se siembran principalmente. En las áreas semi-áridas, la yerba guinea es la principal; la horquetilla es la yerba natural más importante. En la región árida predomina la yerba Bermuda y alguna yerba guinea.

Todos los suelos de esta subdivisión tienen drenaje adecuado o excesivo y muchos están disectados por cientos de canales de drenaje. Muchas de las corrientes fluviales que fluyen por las regiones áridas y semi-áridas están secas la mayor parte del año. Es mucho más difícil obtener agua para el uso humano y de animales que en cualquier otro sitio de la isla. En las orillas del mar y en los valles hay varios pozos y molinos de viento para extraer el agua necesaria para el ganado. El agua que se obtiene cerca de la costa es salobre, por lo tanto, no hay que añadirle sal al agua que toma el ganado. El promedio de profundidad de los pozos es cerca de 35 pies.

En Vieques y Culebra la cantidad de agua, más bien que la cantidad de yerba, determina la capacidad de la tierra para sostener el ganado.

Las áreas de estos suelos que se usan para bosques se adaptan bien al crecimiento de los árboles. En algunos sitios el clima favorece algunas especies y elimina otras; la variación climatérica es suficiente para el crecimiento de cualquier árbol de los que crecen en Puerto Rico.

Los bosques vírgenes en Puerto Rico son limitados en extensión; las únicas áreas que existen están en la Reserva Nacional de Bosques; las otras han sido periódicamente cortadas. En las tierras privadas no se ha seguido una siembra sistemática. Los árboles crecen y se reproducen por selección y eliminación natural. Cuando un árbol se puede vender se corta. El Servicio Insular de Bosques y el Servicio de Bosques Federal han aumentado grandemente sus propiedades en los últimos años, y las han mejorado construyendo caminos y sembrando muchas especies adicionales de árboles. Muchos árboles de valor crecen en algunos de los suelos de esta subdivisión, tales como caoba, cedro, tabonuco, guayacán (lignum vitae), sabino, granadillo y maricao.

El jíbaro acostumbra cortar los árboles para hacer carbón. Este negocio provee algún dinero; pero no es recomendable porque afecta los recursos de bosques de la isla.

Entre los suelos poco profundos de la altura se encuentra un grupo derivado de la caliza dura Terciaria. Son granulosos, plásticos, y de color oscuro. Aquí se incluyen los tipos siguientes: Colinas arcilloso lómico, fase escarpada; Colinas pedrego-arcilloso lómico; Colinas pedrego-arcilloso lómico, fase escarpada; Soller arcilloso lómico, fase poco-profunda; Soller arcilloso lómico, fase en cerros; Soller arcilloso lómico, fase escarpada; Aguilita arcilloso; Aguilita pedrego-arcilloso; y Aguilita pedrego-arcilloso, fase poco-profunda. Todos se dedican más a pastos debido a la poca lluvia y a la capa delgada del suelo. Todos tienen rocas o fragmentos de rocas sobre la superficie en cantidades que varían de sitio a sitio. Los suelos Soller ocupan áreas que reciben de 80 a 100 pulgadas de precipitación pluvial anual; los Colinas reciben menos, o sea de 55 a 80 pulgadas, y los Aguilita son los que reciben menos, de 35 a 55 pulgadas. El color de la tierra, la vegetación, y la clase de cosecha que se siembra, están relacionados con la cantidad de lluvia. Los suelos Soller son casi negros, los Colinas son gris pardo oscuro, y los Aguilita varían de pardo a gris pardo oscuro. La vegetación de los suelos Soller es principalmente mesofítica; en los Aguilita es principalmente xerofítica, y en los Colinas hay ambas. Debido a la lluvia abundante, se cultiva un área mayor de los suelos Soller que de las otras series. Son los mejores para yerbas; le siguen los Colinas y Aguilita.

Cuando no se atienden bien, estos suelos son afectados por la erosión debido a su consistencia plástica pegajosa, a su alto contenido de cal, y a su estructura granular que los hace fáciles de ser arrastrados por las lluvias tropicales. Los suelos Soller han sido más afectados por la erosión, y en iguales condiciones de pendiente, tienen la capa de suelo superficial más delgada que los Aguilita y Colinas. Las cosechas de subsistencia que predominan son gandules, maíz, habichuelas y batatas; con la excepción de batatas, el cultivo de las otras cosechas favorece la erosión.

El relieve escarpado y la naturaleza porosa de la parte baja del substrato hace que estos suelos tengan drenaje excesivo. Muy pocos canales de drenaje los cruzan; el agua se filtra por canales subterráneos. Corrientemente se hace difícil obtener agua para el uso humano y de animales, especialmente durante la sequía. En los cerros quebrados calizos que reciben más de 80 pulgadas de precipitación pluvial hay numerosos manantiales; en las áreas secas el agua se trae de lejos o se recoge la que cae sobre el tejado de zinc de las casas. No se taladran pozos artificiales en estos sitios. Algunos de los cientos de sumideros que existen, en varios sitios, guardan el agua por varios meses.

Derivados de la caliza dura Terciaria se encuentran los tipos de suelos Tanamá pedrego-arcilloso, Ensenada arcilloso, y Ensenada arcilloso, fase poco-profunda. Son rojos o rojo-oscuros, permeables, algo plásticos, granulosos y blandos, neutrales o alcalinos. Se adaptan mejor para matorrales y árboles. Los suelos Ensenada ocurren en las áreas donde el promedio de precipitación pluvial anual es menor de 35 pulgadas; por lo tanto, la vegetación predominante consiste de plantas del desierto. Los suelos Tanamá reciben de 70 á 90 pulgadas de precipitación pluvial anual; su vegetación típica mesofítica consiste de árboles de moca, moral, roble, guaba, capá prieto, ausubo, maría y guaragüao; también existen muchas clases de plantas pequeñas.

El sisal se ha sembrado en algunos sitios; pero ya no se siembra. El magüey crece muy bien en este suelo; esto indica que el sisal podría producirse en los grandes predios de este suelo y otros similares de las regiones semi-áridas.

Los tipos San Germán arcilloso, Lajas arcilloso, y Lajas arcilloso, fase rodante, se derivan de caliza Cretácea. Ocurren en los sitios de relieve rodante y escarpado que están al norte de los suelos Aguilita. Son poco profundos y pedregosos; se usan para pastos y bosques. Los suelos San Germán ocurren en áreas más secas que los suelos Lajas; por esto, generalmente valen menos. Muchos de los suelos Lajas están en áreas cubiertas de piedra caliza que asoma a la superficie; son terrenos baldíos.

Los suelos de las series Jácana, Descalabrado, Guayama y Picacho, lo mismo que los de las series Daguao, Múcara y Naranjito que también pertenecen a este grupo, son derivados de los esquistos de la Cretácea superior, de ceniza y toba estratificada, de toba andesítica maciza, y de conglomerados. Todas estas rocas están íntimamente asociadas; pero a pesar de que cada una de ellas tiene alguna influencia sobre la formación del suelo, la génesis ha sido más bien producto del efecto climatérico. Estos suelos tienen muchas características en común. Son pardos o parduzcos, poco profundos; en su mayor parte ocurren en las partes superiores de las pendientes y sobre las cordilleras altas y angostas que tienen forma de Λ. Debido a la rocosidad, poca profundidad, relieve desfavorable, al clima seco, o al efecto combinado de estas características, de 75 a 85 por ciento de las áreas se dedica a yerbas; el remanente de 15 a 25 por ciento está en maleza, árboles, café, tabaco y frutos menores.

Las áreas de estos suelos se extienden desde la costa sur árida que está a nivel del mar hasta las áreas muy lluviosas del interior. La precipitación pluvial anual aumenta en el orden siguiente de series: Jácana, Descalabrado, Guayama, Daguao, Múcara, Picacho y Naranjito. Algunos de estos suelos ocurren en áreas de precipitación alta,

pero debido a su relieve muy escarpado reciben menos agua que los suelos de las áreas menos lluviosas que tienen relieve menos escarpado.

Existe correlación entre la humedad que recibe el suelo y su color y pH. Generalmente se puede decir que a mayor lluvia, menor es el pH del suelo. Por ejemplo, los suelos Jácana que son los que reciben menos lluvia, tienen pH 7.5, y los Naranjito que reciben la mayor cantidad de lluvia tienen pH 5.0. El color de los suelos Naranjito es algo rojo en los sitios donde llueve más, pero en los sitios donde disminuye la lluvia, los suelos cambian a más oscuros. Los suelos Daguao reciben cerca de 65 pulgadas de precipitación pluvial anual; son casi negros, pero cuando la lluvia disminuye se tornan pardos, pasando por varios tonos de color entre el gris pardo oscuro y nuez oscuro. Los suelos Jácana de las zonas más secas son de color pardo claro.

La lluvia o la humedad del suelo es el factor más importante entre los varios procesos que afectan a este grupo de suelos. Por lo tanto, en muchos sitios, debido al cambio gradual en la distribución de la humedad del suelo, hay también un cambio gradual de un suelo a otro. La línea de demarcación entre dos suelos puede representar aquí más bien una zona de transición que una separación definida de dos suelos.

Los suelos Jácana, Descalabrado y Guayama ocurren en la región árida; casi todos se dedican a pastos. Los muchos ranchos de ganado que se encuentran en esta región la hacen parecer a las grandes llanuras del oeste de Estados Unidos que se dedican a la ganadería. La práctica común es arrancar la maleza y el cactus y luego sembrar yerba de guinea. La yerba es de calidad excelente; el ganado que pasta en estos suelos alcalinos, si no sufre por seca, tiene buena salud y buen pelo, y su carne es dura y firme. La yerba cesa de crecer cuando empieza la sequía, pero se conserva bien y con mucho vigor. Cuando empieza la época de lluvia vuelve a crecer rápidamente. A base de producción, la cantidad de yerba disminuye con la poca profundidad de los suelos y con el clima más seco. Por lo tanto, dentro de cada tipo de suelo, la capacidad que tiene el pasto para sostener el ganado varía mucho porque cada suelo occurre bajo condiciones climatéricas bien variables. En las áreas promedio, el tipo Jácana arcilloso, es el mejor suelo; le siguen en orden los tipos Descalabrado limo-arcilloso, Descalabrado limo-arcilloso, fase rodante, Descalabrado limo-arcilloso, fase erosiva, Descalabrado limo-arcilloso, fase poco-profunda, Guayama arcilloso, y áreas de Guayama arcilloso, fase coluvial.

La mayor parte de las corrientes fluviales dentro del área están secas durante el invierno. Molinos de viento localizados en los valles proveen agua para el ganado y los rancheros. Con la excepción de los sitios donde están los tipos Descalabrado limo-arcilloso, fase erosiva, y Descalabrado limo-arcilloso, fase poco-profunda, ésta es probablemente la parte menos poblada de Puerto Rico a excepción de los bosques nacionales.

Los suelos Daguao, Múcara, Picacho y Naranjito, reciben suficiente lluvia para la producción de árboles y frutos menores. La proporción del área que está sembrada de yerba no es tan alta como la de los suelos Jácana, Descalabrado y Guayama. Basados en su productividad natural los suelos Daguao producen más; le siguen los Múcara, Naranjito y Picacho. Los tipos de los suelos Múcara y Naranjito que se incluyen aquí son: Múcara limo-arcilloso lómico, fase escarpada; Mú-

cara limo-arcilloso lómico, fase poco-profunda; Múcara limoso lómico, fase escarpada, y Naranjito limo-arcilloso lómico, fase escarpada.

Los suelos Yunes y Mariana no se derivan de material similar, pero tienen muchas características en común. Los suelos Yunes se derivan de esquistos ácidos y los Mariana de riolita, de roca silícea fundida de lava y posiblemente de piedra arenisca. Los suelos de ambas series son casi blancos, fuertemente ácidos, plásticos, de estructura de grano simple, y muy poco profundos. Los suelos Mariana se usan para pastos y bosques en la parte oriental de la isla y para piñas y pastos en el área que está cerca de Lajas.

El tipo Vieques lómico, fase escarpada, se incluye en esta subdivisión. Ocupa colinas escarpadas en la parte granítica del oeste de Vieques y al norte de Culebra. Este suelo es similar al tipo Pandura lómico, excepto que ocurre en un clima mucho más seco y tiene una reacción más alcalina. Se usa casi totalmente para pastos; se considera menos deseable para la calidad y cantidad de yerba producida que los tipos Descalabrado limo-arcilloso o Guayama arcilloso. Cerca de las casas de los jíbaros se siembran algunas matas de yerba de guinea.

La tierra quebrada pedregosa se incluye en esta subdivisión. No tiene valor agrícola; se usa sólo para bosques.

Las series Rosario y Nipe son los únicos suelos de Puerto Rico derivados de serpentina. En muchos sitios están íntimamente asociados. Los suelos Nipe son profundos y ocupan las mesetas y pendientes de poca inclinación. Los suelos Rosario ocupan las pendientes escarpadas; son poco profundos. La parte más profunda del área está a lo largo de pendientes cóncavas donde la tierra de las pendientes adyacentes se deposita; como estas pendientes cóncavas tienen más humedad, los procesos que tienden a formar el suelo son más efectivos que en las áreas adyacentes. Ambos suelos tienen una productividad muy baja.

SUELOS DE LAS LLANURAS INTERIORES

Los suelos de las llanuras interiores tienen un relieve variable entre plano, ondulante e inclinado; están situados a distancia considerable del interior y en muchos sitios están rodeados por colinas altas y montañas. Estos suelos incluyen 29 tipos y fases de las series Las Piedras, Mabí, Moca, Dominguito, Río Arriba, Santa Clara y Camagüey, situadas en las regiones húmedas; y las series Yauco, Ponceña, Portugués, Mercedita, Barrancas, Pozo Blanco, Amelia, Río Cañas y Cabo Rojo, situadas en las zonas áridas y semi-áridas.

Salvo raras excepciones, los suelos superficiales son arcillosos, pesados, plásticos y pegajosos, de color oscuro; los subsuelos son plásticos, profundos y pesados. Aunque retienen bien la humedad, son difíciles de arar y cultivar. Aún en tiempos de sequía prolongada, la muestra del subsuelo que se saca con la barrena es húmeda y plástica y se pega tenazmente a la barrena. El poder que tienen las raíces de penetrar fácilmente al subsuelo y substrato contribuye a defender la planta de la sequía. El drenaje artificial se hace necesario en algunos sitios. Estas tierras requieren ser administradas juiciosamente. Si se aran cuando la superficie está húmeda, no se afectan las propiedades físicas que dan al suelo su buena cualidad para el laboreo; pero si se aran muy secos o muy húmedos se forman terrones grandes y pesados que requieren lluvias fuertes para ser desmoronados en gránulos pequeños.

El suelo superficial se seca cuando deja de llover por largo tiempo y se raja en grietas que llegan a un espesor de 2 pulgadas y que profundizan de 10 a 18 pulgadas. Este agrietamiento es perjudicial al sistema superficial de raíces que son alargadas y cortadas debido a la contracción del suelo. Sin embargo, el sistema profundo de raíces está generalmente en buena condición.

La mayor parte de los suelos de este grupo tienen un contenido alto de materia orgánica en la superficie y se adaptan mejor a la caña de azúcar que a cualquier otra cosecha de Puerto Rico. Probablemente, más del 80 por ciento del área está sembrada de caña; su situación cerca de la factoría azucarera contribuye a que la caña se transporte económicamente. El café se da bastante bien en las regiones húmedas cuando estos suelos tienen buen drenaje y declive. El maíz crece muy bien en estos suelos; se siembra frecuentemente en sitios que no están bajo riego y que no son muy accesibles para la entrada de los carros tirados por bueyes. Estos suelos son muy pobres para la producción de citrosas debido al pobre drenaje interno y a subsuelos plásticos y pesados de aereación deficiente. Algunos árboles de toronja que han sido sembrados en los declives convexos de buen drenaje de las zonas húmedas, crecen bastante bien; pero otros sembrados en declives cóncavos, o en sitios de topografía plana, están en muy malas condiciones y probablemente serán reemplazados pronto por caña de azúcar.

Para facilitar la descripción de estos suelos se agruparán las series derivadas de roca madre similar.

La serie Las Piedras, es la única derivada de material granítico. Se parece bastante a la serie Cayaguá con la excepción de que los suelos ocurren en antiplanicies de topografía ondulante, o casi plana, situadas a una elevación de cerca de 500 pies y afectadas moderadamente por la erosión. Tienen buen drenaje; son ácidos y requieren mucho abono. Se usan para tabaco, caña de azúcar, frutos menores y pastos.

Los suelos de la serie Mabí son los únicos de la región húmeda que son derivados de tobas. Son muy similares a los de la serie Juncos, excepto que ocurren en pendientes largas de poca inclinación o en áreas casi planas que están íntimamente asociadas con los suelos Juncos y Múcara. La elevación de estos suelos varía de 10 a 1,000 pies sobre el nivel del mar. Tienen un drenaje regular, son ricos en fertilidad, son neutrales o alcalinos en reacción, y son bastante duros para arar y cultivar. Se usan casi totalmente para caña de azúcar; los rendimientos son muy buenos.

Los suelos de las series Moca, Dominguito y Río Arriba, están íntimamente relacionados. Aparentemente se derivan de esquistos y arcilla de la capa baja de edad Terciaria y ocurren a elevaciones variables entre 250 y 1,000 pies. El suelo de la superficie es plástico, ácido y pesado; y el subsuelo es plástico, pegajoso, ácido, y moteado de rojo, gris y amarillo; el substrato es más friable, cascajoso y ácido, está moteado de rojo, gris y amarillo y es muy plástico cuando está húmedo. Los suelos Moca tienen superficie de color pardo-grisáceo o pardo; la mayor parte está al norte central de la isla íntimamente asociados con los suelos de la serie Colinas. La serie Dominguito ocurre en el centro occidental de la isla; el color de la superficie es casi negro. La serie Río Arriba se encuentra al este; el color de la superficie es pardo-grisáceo.

Estos suelos tienen relieve ondulante; casi toda el área se usa para caña de azúcar, café y frutos menores. Los rendimientos de caña

varían de regulares a buenos; los de café son regulares; y los de frutos menores son muy buenos.

Los suelos de las series Santa Clara y Camagüey, de la región húmeda, y los de las series Yauco, Ponceña, Portugués, Mercedita y Barrancas, de las regiones áridas y semi-áridas, son derivados de material calcáreo, principalmente de piedra caliza. La elevación de estos suelos varía de 10 a 1,000 pies. El suelo superficial es de color gris-pardo oscuro o casi negro, plástico como la cera, alcalino o calcáreo. El subsuelo amarillo, plástico y pegajoso descansa sobre piedra caliza blanda y gris, cuya profundidad varía con la serie. En la mayor parte de los sitios, la inclinación del terreno facilita el drenaje adecuado. El drenaje interno, sin embargo, es lento; en las áreas planas es esencial proveer drenaje artificial.

Estos suelos son bastante ricos en materia orgánica, bases y nutrimentos, pero cuando la caña de azúcar se cultiva contínuamente, necesitan abono comercial a razón de cerca de 700 libras por acre por año. La mayor parte de estos suelos ocurren en áreas uniformes bastante grandes que son fáciles de administrar convenientemente. Si la precipitación pluvial es mayor de 70 pulgadas o si se practica el riego, se siembran de caña de azúcar. Las áreas que no están bajo riego en las regiones áridas y en sitios inaccesibles de las regiones húmedas se dedican a pastos, maíz y frutos menores. Todas las cosechas producidas por estos suelos parecen tener un valor nutritivo alto.

La sal y los álcalis son factores limitantes sólo en una pequeña parte del área total de estos suelos. La clorosis producida por la cal reduce grandemente el redimiento de caña, especialmente en los retoños, en casi todos los sitios de la región árida donde asoma la piedra caliza o donde está dentro de 6 pulgadas de la superficie. En las regiones húmedas; aún sobre la piedra caliza desnuda, esta clorosis sólo afecta seriamente a las piñas.

La tendencia que tienen estos suelos, en algunos sitios, de entrelazarse los unos con los otros, ha obligado a trazar arbitrariamente la línea de demarcación entre muchos de los suelos que están íntimamente relacionados. El color casi negro de la superficie de la serie Camagüey, y gris-pardo oscuro de la serie Santa Clara, es la característica principal que difiere ambas series. Estos suelos ocurren en áreas cuya precipitación pluvial anual varía de 65 a 110 pulgadas. Son algo menos alcalinos y más lavados que los de las series Ponceña y Yauco que ocurren en áreas donde la precipitación pluvial anual varía de 30 a 65 pulgadas. Las relación entre los suelos de la serie Yauco y Santa Clara es la misma que existe entre las series Ponceña y Camagüey.

La serie Portugués difiere de la serie Ponceña en ser más calcárea y en tener la piedra caliza a menos profundidad. La serie Mercedita difiere de la serie Portugués en que se deriva más del aluvión lavado de las colinas calizas cercanas y menos del material residual que da origen a la serie Portugués.

La serie Barrancas difiere de la serie Mercedita en tener una superficie de color más oscuro y en que ocurre en franjas angostas adyacentes a los ríos y quebradas.

Los suelos de la serie Pozo Blanco se derivan del material lavado de piedra caliza medianamente dura. Son de color pardo rojizo y regularmente son friables. En la región árida se encuentran en valles

pequeños. Estos suelos tienen buen drenaje y son granulosos, y productivos si no les falta agua. Muchas plantas, excepto la vegetación xerofítica, sufren por efecto de la sequía. Una proporción muy pequeña está bajo riego y casi todos los sitios se dedican a maíz, frutos menores y pastos.

Los suelos de las series Amelia y Río Cañas se derivan de las tobas y esquistos. Ocupan pendientes largas de poca inclinación o valles cuyas elevaciones varían de 250 a 500 pies. Estos suelos están íntimamente asociados y son algo similares a los de las series Jácana y Descalabrado, excepto que son más profundos, más productivos, y tienen relieve menos inclinado. Son granulosos y de color pardo, pardo oscuro, o casi negro, según la lluvia que reciben; a mayor cantidad de lluvia más oscuros son de color. La roca madre se encuentra a profundidades que varían entre 26 y 36 pulgadas, según sea la pendiente.

Los suelos de la serie Amelia difieren de los de la serie Río Cañas en que no contienen cal libre; los últimos tienen carbonato calizo abundante a profundidades menor de 15 a 20 pulgadas. Muy pocas áreas de la serie Amelia están en situación de poder regarse económicamente en la actualidad. Por lo tanto, se dedican a pastos y tabaco.

Los suelos de la serie Cabo Rojo son similares en características físicas y químicas, a los de la serie Río Arriba, pero ocurren en la región semi-árida y tienen uso algo diferente. La mayor parte de la serie Cabo Rojo se dedica a pastos y caña Uba. Son suelos muy pobres que han sido muy afectados por la erosión laminosa y barrancosa y que ocurren solamente al sudoeste de la isla.

SUELOS ABANCALADOS Y DE ALUVIÓN EN ABANICO

Los suelos abancalados y de aluvión en abanico incluyen los derivados del material lavado de la altura depositado a lo largo y cerca de las corrientes fluviales que ocupan ahora elevaciones que no son afectadas por las inundaciones y que no reciben material adicional sedimentario. Muchos de los bancales ocupan posiciones adyacentes a las corrientes pero están muchos pies sobre la corriente normal porque las fuerzas fluviales naturales y geológicas influyen en profundizar los canales que sirven de curso a las aguas. Generalmente, los suelos abancalados son más viejos que los de aluvión y están más desarrollados.

Los suelos de aluvión en abanico, en las regiones áridas y semiáridas, se forman de material traído al valle por las corrientes fluviales. En estas zonas se originan muchas corrientes intermitentes que vienen de las colinas volcánicas y terminan en los valles de las llanuras costaneras formando aluvión en abanico hasta arropar, en muchos sitios, los suelos de los bajos costaneros. La edad de estos aluviones en abanico varía de reciente a muy vieja. Tanto en los bancales como en los aluviones en abanico, el material del suelo ha reposado por mucho tiempo, de tal modo, que los procesos que trabajan en el suelo han tenido ya efecto sobre la formación de los horizontes.

Muchos de los suelos de este grupo tienen una ligera inclinación hacia el mar o hacia los ríos y tienen por lo tanto, un drenaje natural superficial bastante bueno. Muchos de estos suelos son pesados en textura, tienen capacidad alta para la retención de agua, son profundos, ocupan áreas bastante extensas, y son muy productivos. Se

adaptan bien a la producción de caña de azúcar la cual ocupa de 80 a 85 por ciento del área total.

Los suelos abancalados y de aluvión en abanico se dividen en dos grupos: (1) suelos medianamente friables y (2) suelos compactos.

Los suelos medianamente friables incluyen 40 tipos y fases de las series Torres, Vía, Lares, Fajardo, Humacao y Mayo de las regiones húmedas, y Resolución, Llave, Arcadia, Coamo, Machete, y Vives de las regiones áridas y semi-áridas.

La serie Torres ocupa bancales definidos que se han formado del material lavado de las series Catalina, Cialitos y otros suelos ácidos rojos y púrpura de la altura. En muchos sitios ocurren a elevaciones de más de 1,000 pies. Tienen un suelo superficial friable de bastante espesor, color pardo o pardo-rojizo, sobre un subsuelo muy ácido, permeable, medio compacto, de textura pesada, y de color rojo o rojo-pardo. El substrato es friable, tiene una textura lómica, es ácido, su color es rojo claro, y está estratificado con capas de rocas y grava pulidas por las aguas.

Estos suelos han sido muy lavados y son bastante pobres en bases y materia orgánica. Sin embargo tienen un relieve favorable para la agricultura general y tienen adecuado drenaje interno o externo. Generalmente podemos decir que los suelos de la serie Torres se adaptan bien a la producción de casi todas las cosechas de Puerto Rico y dan rendimientos regulares o medianos si se abonan adecuadamente. La siembra de leguminosas y aplicaciones de cal y estiércol ayudarán a aumentar los rendimientos y a mantener la fertilidad del suelo.

La erosión debe prevenirse cuando se cultivan pendientes mayores de 15 por ciento. Algunas áreas que han sido muy afectadas por la erosión laminosa y por la erosión barrancosa se usan solamente para pastos.

La serie Vía ocurre en bancales ondulantes y en aluviones en abanico a lo largo de los lados de los valles de los ríos a elevaciones de menos de 250 pies y donde las corrientes de los ríos han traído abundante mezcla de grava y detritus de las tobas de las colinas superiores. El material ha sido depositado por tiempo suficiente para que los procesos activos en la formación de los suelos hayan desarrollado un perfil bastante definido. La textura del suelo y el grueso de cada uno de los horizontes del perfil varían de acuerdo con la localidad. Dentro del área de estos suelos hay muchos predios de drenaje pobre que necesitan ser drenados artificialmente y hay también muchos pequeños predios de grava que son secos e improductivos.

Derivados en su mayor parte, del material lavado de la serie Múcara y otros suelos asociados, jóvenes y de reacción neutra, estos suelos tienen un contenido mayor de bases y nutrimentos que los de las series Torres y Lares, formados del material traído de suelos más viejos y más lavados. Los suelos de la serie Vía son de fertilidad pobre debido al lavado algo extenso de las lluvias. Es necesario tratarlos con aplicaciones de abonos comerciales y encalarlos ocasionalmente. La siembra de leguminosas y la incorporación de su abono verde sería beneficioso.

Los suelos de la serie Lares tienen características físicas y posición similar a los de la serie Torres; pero son derivados de material lavado de las arcillas y esquistos terciarios; están situados generalmente al sur de y paralelos a la formación caliza que se extiende desde Moca

hasta cerca de Bayamón. Su elevación varía de 30 a más de 1,000 pies sobre el nivel del mar. Estos suelos tienen buen desarrollo; en un tiempo eran planos; pero ahora, debido a los numerosos cursos de drenaje natural, muchas áreas tienen topografía inclinada y escarpada. Las áreas más planas se adaptan bien a la producción de casi todas las cosechas de la isla; del 85 a 90 por ciento están sembradas de toronjas, caña de azúcar, café, piñas y frutos menores. El número de cuerdas dedicadas a cada uno de estos cultivos es más o menos igual. Las áreas escarpadas se dedican a café y pastos.

Los suelos de la serie Fajardo están íntimamente asociados con los de la serie Río Piedras; se derivan del material lavado de estos suelos y de la serie Yunes. Son residuales en algunos sitios, en otros coluviales, y en otros aluvión viejo. La mayor parte de las áreas tiene una elevación menor de 500 pies. Su topografía, desde las colinas adyacentes hasta los canales fluviales, es ligeramente inclinada; muchas de las áreas son largas y estrechas. En su mayor parte están situados cerca de las centrales azucareras. Están sembrados casi totalmente con caña de azúcar, la cual produce cerca de 35 toneladas por acre, año tras año, si se abonan adecuadamente.

El suelo superficial es oscuro, pesado, ácido y plástico, cuando está húmedo. El subsuelo es una arcilla ácida moderadamente compacta de color rojizo-pardo y de estructura cúbica. El substrato es de una arcilla moteada de rojo, y amarillo-pardo, de estructura cúbica, que se extiende muchos pies hacia adentro.

Los suelos de las series Humacao, Mayo, Resolución, Llave y Arcadia, son derivados, todos o en parte, de material granítico similar; y ocurren a elevaciones que varían entre 10 y 150 pies sobre el nivel del mar. Las series Humacao y Mayo se forman en la parte este-central de la isla, donde la precipitación pluvial anual varía de 70 a 80 pulgadas. Los suelos Resolución, Llave y Arcadia, ocurren sólo en Vieques donde la precipitación pluvial anual es cerca de 40 pulgadas. Los suelos de las series Humacao y Mayo tienen color más claro, son más lavados, y son mucho más ácidos que los suelos de Vieques, derivados de granito. La serie Humacao tiene un subsuelo más pesado que la serie Mayo y se adapta mejor a la caña de azúcar que ocupa casi la totalidad del área. Ambos suelos son de color claro y tienen un substrato arenoso y friable. Están bien avenados y ocupan los bancales y aluviones en abanico. La serie Humacao ocupa, más o menos, posiciones definidas en los bancales, y la serie Mayo ocupa los aluviones en abanico. La variedad principal de caña sembrada en estos suelos es B. H. 10 (12), la cual se siembra en chorro y se abona fuertemente con abonos comerciales altos en nitrógeno. Estos suelos no están bajo riego.

Los suelos de la serie Resolución son más oscuros, más profundos y más productivos, que los de las series Llave y Arcadia. La serie Llave ocupa posiciones definidas en los bancales y se deriva totalmente de material granítico; los suelos Resolución y Arcadia, se derivan también de tobas. Estos suelos ocupan un área pequeña; son regularmente productivos para caña de azúcar y maíz. Los suelos de Vieques no se riegan porque falta el agua; muy pocos se abonan. Aparentemente no paga abonar la tierra en las regiones áridas; aunque la caña de azúcar aparenta buen desarrollo las raíces no penetran profundamente para buscar agua, y durante la sequía, la planta sufre por falta de humedad. La caña de azúcar se siembra aquí en chorros

profundos y las cañitas o semillas se siembran más separadas que en las regiones húmedas o bajo riego. Rendimientos de caña de 20 a 25 toneladas es considerado bueno en estos suelos. La práctica común es sembrar caña S. C. 12/4 y Uba y cultivar muchos retoños. La variedad Mayagüez 28 ha producido rendimientos regulares en algunos de estos suelos.

Los suelos de la seri Coamo están situados en las regiones semi-áridas en bancales cuya elevación varía de 300 a 500 pies. Estos suelos se derivan del material lavado de los suelos pardos, poco profundos, y alcalinos de la serie Descalabrado. Estos suelos son calcáreos, de color oscuro, de textura pesada, y ricos en materia orgánica y bases. Debido a su posición, un área muy pequeña de estos suelos se riega en la actualidad; como el 80 por ciento se dedica a pastos. La caña de azúcar se daría muy bien si fuera posible conseguir agua abundante.

Los suelos de las series Machete y Vives están situados en los bancales y aluviones en abanico de las regiones semi-áridas cuya elevación es menor de 250 pies. Se derivan del material lavado de los suelos pardo rojizos y alcalinos de la serie Guayama. La superficie de la serie Machete tiene un color pardo-rojizo, mientras que el de la serie Vives es gris pardo oscuro. Por lo demás, son muy similares. El subsuelo es medio friable, pesado, alcalino o neutral, y rojo o pardo-rojizo. El substrato es más liviano en textura, más friable y menos rojo que la superficie. Casi toda el área de estos suelos está bajo riego y sembrada de caña de azúcar que produce de 55 a 70 toneladas de gran cultura por acre, 40 a 50 toneladas de primavera, y 30 a 35 toneladas en los retoños. B. H. 10 (12), la variedad principal de caña, se siembra en chorros, y se abona con 300 a 400 libras de 12–8–4 y 300 libras de sulfato amónico en la segunda aplicación; se riega de 12 a 20 veces, según la estación y período de crecimiento.

Los suelos compactos de los bancales y aluviones en abanico incluyen 26 tipos y fases de las series Fraternidad, Paso Seco, Fé, Santa Isabel, Teresa y Candelero. Todos estos suelos, con excepción de la serie Candelero, ocurren en las regiones áridas y semi-áridas, y son derivados principalmente del material lavado de piedra caliza, tobas y esquistos. Su elevación varía desde pocos pies a 200 pies sobre el nivel del mar. Estos suelos son profundos, casi planos, alcalinos o calcáreos, ricos en bases, y muy productivos. El suelo superficial es granuloso y el color varía de pardo claro a gris pardo muy oscuro, o casi negro, dependiendo de la cantidad de lluvia anual que han recibido desde que el material se depositó por primera vez. Mientras mayor sea la lluvia, más densa es la vegetación, y por lo tanto, el color del suelo es más oscuro. Cuatro o cinco millas de norte a sur, el promedio de precipitación pluvial disminuye de 15 a 20 pulgadas, y ésto tiene un efecto decisivo en el color del suelo.

Los suelos de la serie Fraternidad ocupan pendientes largas de poca inclinación que se extienden desde las faldas de las colinas volcánicas y calizas hasta los suelos de los bajos costaneros y de aluvión; en algunos sitios, los primeros arropan los segundos. Estos suelos se derivan de material que es residual en parte. Tienen un suelo superficial color pardo o pardo-grisáceo muy oscuro; son calcáreos, pesados y granulosos; el subsuelo es compacto, de color pardo amarillento, es pesado y calcáreo, y tiene numerosas concreciones calizas. El substrato es una arcilla calcárea color pardo-amarillento claro, más

friable que el subsuelo y contiene numerosos fragmentos angulares de rocas. La mayor parte de estos suelos están al sudoeste de la isla. Tienen buen drenaje interno y externo. El drenaje natural se hace efectivo por canales pequeños y profundos formados por corrientes fluviales intermitentes que se desbordan totalmente cuando llueve torrencialmente.

Los suelos de la serie Paso Seco son similares en características físicas y posición a los de la serie Fraternidad; pero no contienen cal libre. Ocurren en los bancales y aluviones en abanico y en algunos sitios arropan los suelos de los bajos costaneros y de aluvión.

La serie Fé difiere de la Fraternidad en el color distintivo púrpura-pardoso o púrpura del subsuelo, y pardo-purpúreo del substrato. Se derivan de material de aluvión viejo, y en muchos sitios, están sobre capas estratificadas de arena y grava a una profundidad menor de 4 pies. En muchas áreas, especialmente al noreste de Coquí y al noroeste del lago Guánica, aparecen numerosos promontorios conocidos por "tumores" sobre las áreas pobremente drenadas de los suelos de la serie Fé. Muchos de estos tumores tienen una altura de 3 a 4 pies y un largo de 10 a 15 pies y se asoman sobre el nivel del terreno. La suspensión acuosa coloidal arcillosa que está dentro del tumor es cubierta por una capa de barro dura de 8 ó 12 pulgadas de espesor, con la excepción de una grieta larga y continua que se extiende sobre la cubierta, y que corre longitudinalmente con el promontorio. De aquí salen agua y limo del suelo cargados con carbonato sódico durante la estación de lluvias o cuando la presión del agua subterránea que corre al mar es suficientemente fuerte. Muchos de estos tumores tienen más de 15 pies de profundidad y son peligrosos para el ganado porque los animales que caminan sobre ellos pueden romper la capa superficial endurecida y hundirse inmediatamente en la suspensión coloidal. Muchos de ellos están cercados; otros están en su condición natural; las eneas crecen próximas a las áreas menos saladas.

Los suelos de la serie Santa Isabel son de color pardo o pardo claro en todo el perfil; pero el subsuelo tiene generalmente un tinte pardo-amarillento. El suelo superficial es medianamente friable, alcalino y granuloso. El subsuelo es muy compacto, limoso y columnar. El substrato es friable y está estratificado con arena y capas de grava a profundidades variables de 4 á 5 pies. Estos suelos son similares a los de la serie Fraternidad con excepción de que son definitivamente derivados de aluvión viejo según se ve en las capas subsiguientes de grava.

Los suelos de la serie Teresa se pueden comparar con los de la serie Santa Isabel que tienen drenaje pobre; muchos tienen un alto contenido de sal y álcali.

Casi toda el área regada de estos suelos se siembra de caña de azúcar, que produce de 30 a 100 toneladas por acre. La mayor parte de la caña se siembra de chorro, a cuatro pies de separación, y se riega de 10 a 16 veces dependiendo del período de crecimiento y la cantidad de lluvia. Las principales variedades de caña de azúcar que se siembran son B. H. 10 (12), P. O. J. 2878, y Co-281; pero probablemente más del 80 por ciento es B. H. 10 (12). La cantidad y fórmula de abono, comúnmente usada, es cerca de 300 libras del 12-8-4 y 300 libras de sulfato amónico como segunda aplicación.

Las áreas de estos suelos que no son afectados por álcali y que no están bajo riego producen una buena calidad de yerbas de guinea, Bermuda y horquetilla. Sostienen una cabeza de ganado por acre por año. Algunas áreas están sembradas de maíz que produce cerca de 20 fanegas por acre.

Las áreas afectadas por sal y álcali se usan para el pastoreo de los bueyes de trabajo propiedad de las centrales; su valor es un décimo del precio de las áreas libres de sal. Estas áreas producen vegetación halófila y yerbas y árboles que toleran la sal. Las yerbas Bermuda y horquetilla crecen si el contenido salino no es alto.

Los suelos de la serie Candelero se encuentran en la zona húmeda situada en la parte oriental del centro de la isla. Estos suelos se han derivado del material lavado de las colinas situadas sobre rocas de cuarzo y diorita de grano grueso. Estos suelos son grises, ácidos y arenosos al tacto, y como han sido lavados, son pobres en bases y nutrimentos. Tienen un subsuelo de color gris, muy compacto, casi impermeable, que impide el desarrollo de las raíces y la percolación. El agua penetra rápidamente el suelo superficial y corre lateralmente a lo largo de la parte superior del subsuelo hacia los sitios de drenaje. El substrato, a una profundidad de 20 a 60 pulgadas, consiste de rocas de cuarzo parcialmente desintegradas.

Los suelos de la serie Candelero se usan extensamente para caña de azúcar, pero los rendimientos son bajos, aún aplicando 700 a 800 libras de abono, y teniendo una lluvia adecuada. La mayor parte de la caña de azúcar que se cultiva, B. H. 10 (12), se siembra en chorro o en bancos de poca altura.

SUELOS DE LAS LLANURAS COSTANERAS

Los suelos de las llanuras costaneras tienen muchas características en común. Son profundos, casi llanos, razonablemente fértiles, y de reacción neutral o fuertemente ácida. La textura está entre la arenosa y arcillosa y el color entre rojo o amarillo y negro a blanco. El color dominante es rojo. Este grupo no incluye los suelos poco profundos de las pendientes empinadas de la llanura costanera, suelos que se derivan de los depósitos de piedra caliza de la edad Terciaria; éstos se incluyen con los suelos de la altura.

De acuerdo con sus características físicas los suelos de las llanuras costaneras se dividen en cuatro subdivisiones: (1) suelos compactos; (2) suelos friables; (3) suelos muy friables; y (4) suelos arenosos. Los suelos de cada subdivisión son adaptables a ciertas cosechas específicas.

Los suelos compactos de la llanura costanera son más difíciles de administrar que otros suelos de la isla debido a la condición pesada, tenaz, e impermeable del subsuelo. Esta subdivisión incluye los tipos de las series Sabana Seca y Caguas, suelos de color gris-pardoso derivados probablemente de depósitos marinos viejos y del material mezclado lavado de la altura; los suelos de la serie Almirante y las fases de subsuelo pesado de la serie Vega Baja, ambos derivados de piedra caliza Terciaria; y los tipos de suelos de la serie Islote derivados de piedra caliza arenosa.

Estos suelos ocurren en las llanuras costaneras del norte y en los valles interiores. Sin embargo, muchas de las áreas no se extienden más de 5 millas detrás de la costa; todos tienen topografía casi plana u ondulante. Muchos de estos suelos reciben una precipitación

pluvial anual de 60 a 75 pulgadas, suficiente para la producción de cosechas. Algunas de las fincas de caña y citrosas están bajo riego.

Las cosechas principales que crecen en estos suelos son: caña de azúcar, frutos menores, piñas y yerbas. Los rendimientos están debajo del promedio para las llanuras costaneras y son mucho más bajos que los de los suelos de aluvión.

Los suelos de esta subdivisión varían en elevación desde pocos pies a cerca de 500 pies sobre el nivel del mar. La precipitación pluvial varía de cerca de 50 pulgadas próximo a Lajas e Isabela, a 75 pulgadas cerca de Bayamón y Florida. Algunos de los suelos ocurren en áreas pequeñas en todas las 100 millas de extensión de la costa norte. Entre estos suelos hay alguna variación de características físicoquímicas, especialmente en la acidez y cantidad de agua que ha lavado el perfil del suelo. Generalmente, las áreas que reciben 50 pulgadas de precipitación pluvial anual tienen un pH cerca de 6.0 y los suelos no son tan lavados como los que reciben 76 pulgadas cuyo pH es de 4.5.

El horizonte superficial de estos suelos es plástico y tenaz; por lo tanto, el margen de humedad para el cultivo propio de la tierra es muy reducido. Si se aran cuando están muy húmedos forman un amasijo; y muy secos, forman terrones grandes y duros. Estos suelos son sensibles a la sequía y los rendimientos se reducen grandemente si las lluvias no caen a su debido tiempo. Responden bien al riego adecuado. El cultivo es más costoso que en los otros suelos de las llanuras costaneras; con buen juicio en el cultivo y con abonamiento se les saca provecho mediano.

La S. C. 12/4 es la variedad de caña que, hasta la fecha, da los mejores resultados; su sistema de raíces penetra el subsuelo duro y tenaz donde recoge nutrimentos y agua para la planta. Como el subsuelo es tan duro y ejerce tanta presión cuando se expande y contrae, entre los cambios extremos de humedad, las raíces de casi todas las plantas que lo penetran se deforman grandemente, algunas son chatas, otras dobladas, y otras se rajan en dos. Este efecto reduce la eficiencia de las raíces para proveer a la planta con agua y nutrimentos. Las raíces tienden a seguir las vetas grises del subsuelo más bien que las rojas y oscuras; siguen, por lo tanto, el material gris y más blando que tiene mayor contenido de alúmina y arcilla y menos arena y hierro.

Los suelos de este grupo pueden mejorarse con el arado profundo o usando un arado potente como el "gyrotiller" para romper la parte superior del subsuelo duro y tenaz. Cuando este subsuelo se ablanda y desmorona no vuelve a cementarse y a endurecerse tan rápidamente como sucede con los suelos de las series Moca, Santa Clara y Camagüey.

Los análisis químicos de estos suelos indican que en muchos sitios son pobres en nutrimentos y por lo tanto es conveniente abonarlos. La cantidad y fórmula de abono corrientemente usada en las plantaciones de caña es 600 libras del 12–8–5 aplicadas 6 semanas después de la siembra y 400 a 500 libras de sulfato amónico aplicadas de 6 a 8 semanas más tarde.

Los suelos friables de las llanuras costaneras incluyen los suelos de textura pesada de las series Bayamón, Coto, Espinosa, Matanzas y Vega Alta; todos derivados de piedra caliza medianamente dura. Estos suelos ocurren en valles planos ondulantes formados por la disolución y erosión de las estratas blandas de la piedra caliza. Ocurren en la zona caliza de la costa norte, entre Aguadilla y el este de Carolina; su elevación fluctúa entre 100 y 600 pies sobre el nivel del mar. Estos

suelos son pesados, permeables, y de reacción neutral o ácida, y poseen un número de características importantes y peculiares de algunos suelos tropicales. Tienen propiedades físicas y químicas similares, desde la superficie hasta la roca madre. Tienen un alto por ciento de partículas arcillosas agrupadas de tal modo que influyen más bien en darle al suelo las características físicas favorables que poseen los suelos lómicos o lómicos arenosos que las típicas de los suelos arcillosos. Húmedos, estos suelos son algo pegajosos y resbalosos; pero no tanto como otros suelos que tienen el mismo por ciento de arcilla. Secan rápidamente y pueden cultivarse pronto después de la lluvia. Si se trabajan húmedos, los terrones grandes producidos se desmoronan en partículas más pequeñas después del primero o segundo aguacero. Estos suelos arcillosos no expanden cuando están mojados ni se rajan cuando se secan. No importa las condiciones de humedad, el agua penetra por ellos libremente, excepto en los suelos de la serie Vega Alta. Esto demuestra que tienen naturaleza porosa. Por lo tanto, es evidente que los poros de los capilares están abiertos continuamente y que no se tupen por la expansión del suelo mojado. El agua los penetra rápidamente, pero no es retenida como en los otros suelos arcillosos; durante la sequía estos suelos se secan hasta gran profundidad. La naturaleza porosa de estos suelos hace que la evaporación sea excesiva; se necesitan, por lo tanto, lluvias y riegos frecuentes para obtener buenos cosechos. La percolación rápida contribuye al lavado de muchos nutrimentos y del abono añadido hacia la parte baja del subsuelo que no es accesible a las raíces. Estos suelos, por lo tanto, no son muy productivos, a pesar de que tienen facultades propias para el buen laboreo y un subsuelo profundo.

Los suelos de la serie Coto se reconocen por el color amarillento del subsuelo arcilloso y los de la serie Matanzas por el color rojo brillante. Los suelos de las series Espinosa y Bayamón corresponden a los suelos ácidos de las series Coto y Matanzas, respectivamente; las primeras dos series ocurren desde Río Piedras a Arecibo donde el promedio anual de precipitación pluvial es más de 60 pulgadas; las series Coto y Matanzas se encuentran entre Arecibo y Aguadilla donde la precipitación pluvial anual es menor de 55 pulgadas. La mayor parte de los suelos de la serie Vega Alta se encuentra donde la precipitación pluvial anual es mayor de 65 pulgadas; son muy ácidos, han sido muy lavados, y su color es más claro y su subsuelo está más moteado; tienen también drenaje más imperfecto que los otros suelos de esta subdivisión.

Es característica notable en el área donde ocurren estos suelos observar la falta de ríos y de canales de drenaje. El exceso de agua drena por sumideros y depresiones; algunos retienen el agua. Estas depresiones son numerosas cerca del poblado de Florida. El agua empozada es usada por la gente y los animales, pero en muchos sitios la cantidad de agua no es suficiente para durar todo el tiempo de sequía. Miles de personas viven del producto de estas tierras; hay muchas casas en toda el área. Las fincas son pequeñas con excepción de las que poseen las centrales azucareras.

La erosión es insignificante en estos suelos porque tienen un relieve casi plano y son permeables a los lavados interiores. Hay alguna erosión cerca de los sumideros donde se nota que el borde tiene la cubierta superficial del suelo menos profunda que en las áreas adyacentes. Cerca del fondo del sumidero el suelo tiene un color oscuro

hasta una profundidad considerable; esto indica sedimentación y un alto contenido de materia orgánica.

Análisis químicos y experimentos de abonos en el campo indican que todos estos suelos son pobres en nutrimentos; sin embargo, casi todos se cultivan en su totalidad. Los rendimientos varían con las condiciones climatéricas y las prácticas agronómicas; generalmente estos suelos no han sido productivos para la caña de azúcar. Ocurren en zonas climatéricas de precipitación pluvial variable. Los situados en las áreas que reciben menos de 65 pulgadas (gráfica 35) de lluvia anual, si no son regados, son menos productivos que los situados en las áreas más lluviosas. Rendimientos mayores de 50 toneladas de caña por acre no son muy corrientes; estos se obtienen en los suelos de aluvión, en algunos de los situados en bancales, y en algunos de la altura. En muchas de las áreas el riego aumentaría el rendimiento de caña, 10 ó 15 toneladas por acre. Las variedades que crecen mejor son P. O. J. 2725 y P. O. J. 2878. Las variedades Mayagüez 28, P. R. 809, y F. C. 916 parecen prosperar bien en los sitios donde han sido sembradas. La S. C. 12/4 prospera bien pero es indeseable por su susceptibilidad al mosaico. Se abona con las fórmulas 12-6-5 y 10-10-8, aplicando cerca de 800 libras por acre en la primera aplicación y 200 libras de sulfato amónico, 100 días más tarde. Hasta la fecha los experimentos de abono [26] en el tipo Coto arcilloso, indican que las siguientes cantidades de abono son las mejores: 100 libras NH_3, 30 libras P_2O_5 y 120 libras K_2O; ó 100 libras NH_3, 60 libras P_2O_5 y 60 libras K_2O. Este suelo es representativo de la subdivisión.

El tabaco de mascar crece muy bien en estos suelos y es la segunda cosecha de importancia. La variedad principal sembrada, Virginia Blanca, produce cerca de 600 libras por acre. Las piñas crecen muy bien en las series Espinosa, Vega Alta y Bayamón; las series Coto y Matanzas son de reacción ligeramente alcalina, y no producen buen cosecho de piñas. La variedad "Hispano Roja" (Red Spanish) se siembra principalmente. Produce de 200 a 250 cajas por acre en la primera cosecha, cerca de 150 a 200 cajas en el primer retoño y cerca de 100 cajas en el segundo retoño. Los árboles de toronjas crecen bastante bien, pero no tan bien como en las series de textura más arenosa. También producen buenas cosechas de chinas, plátanos, batatas, ñames, pimientos, pepinillos y yuca.

Es notable observar partículas de arena en todo el perfil de estos suelos, cuya cantidad disminuye con la profundidad. Hay menos arena en los tipos pesados. Un terrón de esta tierra seca, prensado entre los dedos, se desmorona en muchos granos individuales que parecen arenosos, pero al mojarse y palparse al tacto se observa que ni son plásticos ni arenosos; esto demuestra que aunque probablemente tienen alguna arena, mucho del material es arcilla. Los análisis mecánicos demuestran que de 60 a 95 por ciento del material de la superficie es arcilla, y el remanente de 5 á 40 por ciento tiene cantidades idénticas de arena media, arena fina, arena finísima y limo.

El análisis mecánico, usado en la actualidad, se basa en separar y clasificar la textura en clases, de acuerdo con la proporción y diámetro de las partículas que componen el suelo. Todo suelo que contenga

[26] Trabajo experimental de L. A. Serrano, director de la Subestación Experimental Agrícola, Isabela, P. R.

más de 40 por ciento de partículas cuyo diámetro sea menor de 0.005 milímetros se clasifica como suelo arcilloso. En el campo se observa que un suelo de la serie Coto que tiene 60 por ciento de arcilla es más fácil trabajarlo y se adapta al cultivo de más clases de cosechas que cuando tiene 90 por ciento de arcilla. El análisis mecánico, en ambos casos, clasifica este tipo de suelo como Coto arcilloso. Para diferenciar este grupo de suelos reconocidos como lateríticos, la textura del tipo Coto arcilloso, se subdivide en dos clases: Coto arcilloso, fase pesada, cuando tiene cerca de 90 por ciento de arcilla en el horizonte superficial; y Coto arcilloso, cuando solo tiene cerca de 75 por ciento.

Los suelos de las llanuras costaneras que tienen subsuelos bien friables son los mejores suelos de Puerto Rico para toronjas. Incluye los tipos de textura arenosa de las series Vega Alta, Espinosa, Coto, Bayamón, Maleza, Islote y Río Lajas; todos derivados de piedra caliza. Los suelos Vega Alta, Espinosa, Bayamón y Río Lajas ocurren en regiones húmedas o semihúmedas; por lo tanto, son ácidos y sus perfiles han sido lavados. La serie Vega Alta ha sido más lavada que las otras. Las series Coto, Maleza y Islote ocurren en regiones semiáridas; son suelos menos ácidos y sus perfiles han sido menos lavados. Estos suelos tienen casi idénticas características que los de textura pesada de la misma serie con excepción de que son más sueltos, más friables, de textura más liviana, y tienen el horizonte superficial más profundo y el subsuelo algo más friable y menos pesado. Como estos suelos son más permeables, más sueltos y arenosos, se adaptan mejor para toronjas y hortalizas que los de textura pesada; pero no se adaptan bien para caña de azúcar. Los árboles de toronjas que crecen en estos suelos florecen temprano y abundantemente; con riego, dan fruta de tamaño grande. Las tres cosechas principales que crecen en los suelos de estas siete series son caña de azúcar, toronjas y tabaco. La caña produce de 10 a 15 toneladas en las arenas lómicas, 15 a 20 toneladas en los tipos arenosos lómicos y 35 a 50 toneladas en los suelos de textura pesada. Bien administrados, producen 15 a 25 cajas de toronjas en las arenas lómicas, 7 a 15 cajas en los tipos arenosos lómicos y 3 a 7 cajas en los de textura pesada. Un árbol de 6 años produce como dos veces más que uno de tres años. Las arenas lómicas producen como 300 libras de tabaco por acre; los tipos arenosos lómicos 500 libras, y los de textura pesada como 600 libras.

En aquellas plantaciones de toronjas que tienen suelos adyacentes de textura arena lómica, lómico arenoso, y arcillosa se nota que los árboles sembrados en arena lómica son como dos o tres veces mayores que en el tipo arcilloso de la misma serie. Los árboles en el tipo lómico arenoso son tan buenos como los árboles más pequeños en el tipo de arena lómica. En una plantación que tiene árboles de 17 años y que está bien administrada, los árboles en el tipo de arena lómica han llenado todo el espacio accessible y aquellos que crecen en el tipo arcilloso tienen sólo una tercera parte del tamaño de los primeros, han llenado sólo cerca de la mitad del espacio y ha habido que sembrar otros arbolitos de toronjas entre los árboles grandes. Esta gran diferencia entre el crecimiento de los árboles no es muy notable, en los primeros años o en años posteriores, si se ha practicado el riego continuamente y si la precipitación pluvial anual es más de 80 pulgadas.

La cantidad y fórmula de abono que se usa en las plantaciones de toronjas es de 30 a 35 libras del 6-8-10 para árboles que produzcan cerca de 20 cajas de fruta y como de 15 a 20 libras si los árboles producen cerca de 10 cajas.

Una característica notable en los tipos lómicos arenosos, y en cantidad menor, en las arenas lómicas, de todas estas series de suelos, es la presencia de una gran cantidad de concreciones de hierro, o perdigones, en la parte inferior del horizonte superficial. Si debido a la erosión, o a otra causa, se ha removido dicho horizonte de tal modo que muchos de los perdigones ocurran sobre la superficie del suelo, el valor agrícola de éste se reduce grandemente. Los rendimientos se reducen debido a la poca profundidad del horizonte superficial y a la cercanía del subsuelo pesado; se cree que el perdigón afecta poco las cosechas. Todos estos suelos son pobres en fertilidad lo mismo que lo son los suelos arenosos.

Los suelos arenosos de las llanuras costaneras incluyen las series Guayabo, Corozo, Algarrobo y St. Lucie. Estos suelos se distinguen fácilmente de todos aquellos ya descritos porque tienen una superficie de arena suelta de color gris pardo claro, o casi blanca, o casi negra; y subsuelos arcillo-arenosos, medio pesados y tenaces, moteados de rojo, pardo y gris y que están, en muchos sitios, a más de 4 pies de la superficie. Estos suelos ocurren en los sitios de las llanuras costaneras que tienen relieve plano u ondulante, y que generalmente están a una distancia de la costa, no mayor de 2 millas. A pesar de ser bien arenosos, no tienen drenaje excepcional, excepto en las fases profundas. El agua percola muy fácilmente por la capa superficial; pero el subsuelo pesado, de más o menos permeabilidad, retarda el movimiento descendiente del agua, y ésta corre lateralmente sobre el subsuelo.

Estos suelos contienen una pequeña cantidad de nutrimentos; primero, porque su productividad inherente es baja debido a la textura gruesa del suelo superficial, y segundo, porque los nutrimentos solubles han sido lavados por el efecto de mucha lluvia y porque el suelo es ácido, poroso y pobre en materia orgánica. Todo esto contribuye también a lavar el abono comercial que se le añade a la cosecha; por lo tanto, es más eficiente añadir el abono periódicamente en pequeñas cantidades. Es preferible usar estiércol de cuadra porque no se lava con facilidad, sostiene sus nutrimentos más tiempo para el uso de la planta, y también enriquece la arena con materia orgánica, lo que a su vez aumenta la capacidad del suelo para el intercambio de bases. Siembras de leguminosas como Crotalaria y fríjoles son muy buenas para estas arenas, pero su efecto es de corta duración. La mejor clase de estos suelos es utilizada principalmente para hortalizas; el algodón se siembra en algunas áreas. Los tipos mejores son fáciles de cultivar y responden al abono o estiércol; pero los tipos más pobres y ácidos se dedican a pastos o se abandonan. La caña de azúcar corrientemente es un fracaso completo. La changa destruye mucho las cosechas sembradas en estos tipos arenosos. Es sumamente prohibitivo regar estos suelos porque requieren enorme cantidad de agua. El tipo de suelo, Guayabo arena fina, fase poco-profunda, es el que requiere menos agua.

SUELOS DE LOS VALLES DE ALUVIÓN

Los suelos recientes de aluvión incluyen las tierras de mayor producción y precio dedicadas al cultivo de caña de azúcar. Algunas de las plantaciones de toronjas y piñas se cotizan a precios altos, pero la tasación incluye la tierra con su cosecha. Los suelos de aluvión son excelentes tierras agrícolas; el cultivo de la caña se intensifica en ellos contínuamente, año tras año. Más del 90 por ciento de estos suelos se dedican a caña de azúcar. La mayoría del 10 por ciento remanente se dedica a malojillo, única cosecha que puede competir con la caña en las condiciones prevalecientes del valor alto de estas tierras. Algunas de las mejores áreas se venden a un precio mayor de $700 por acre, no incluyendo el valor de los edificios y las cercas.

Los suelos de este grupo se han formado y enriquecido del material que arrastran periódicamente las aguas desde la tierra montañosa del interior. La velocidad del agua influye en la capacidad de arrastre de las partículas; las arenas y el cascajo se quedan en la orilla de las corrientes fluviales donde el agua modera su velocidad; ahí se acumulan hasta varios pies sobre el nivel del terreno. Las partículas finas de arcilla son arrastradas más lejos y depositadas en las depresiones situadas cerca de los bajos costaneros de drenaje pobre. Generalmente, el terreno es más pesado y el drenaje interno es más imperfecto según se aleja éste del curso de las corrientes.

Los suelos de los valles de aluvión se dividen en dos grupos: (1) suelos de buen drenaje, o situados bastante cerca de las corrientes fluviales, y (2) suelos de drenaje pobre, o aquellos lejos de las corrientes fluviales y asociados con los mejores suelos de drenaje pobre en los bajos costaneros.

Los suelos de aluvión de buen drenaje incluyen las áreas más productivas; en algunos de éstos, se han obtenido los rendimientos más altos de caña de azúcar. Caña de gran cultura ha producido 100 ó más toneladas de caña, o cerca de 13 toneladas de azúcar por acre. Los suelos de este grupo son friables, profundos, y tienen buen drenaje. Estos suelos son de topografía casi llana, ocurren a lo largo de los canales de las corrientes fluviales y se inundan durante el período de lluvia excesiva. El limo arrastrado por las aguas rejuvenece estos suelos y contribuye a hacerlos productivos.

Este grupo incluye 37 tipos de suelos y fases de las series Toa, Estación y Viví, en la región húmeda; de las series San Antón y Altura en las regiones áridas y semi-áridas, y lavado de río que se encuentra en ambas regiones.

Los suelos de la serie Toa son de reacción neutral o ligeramente ácida porque son producto del material lavado de las colinas calcáreas y de los suelos asociados a la serie Múcara. Son bastante ricos en bases y alimento para las plantas a pesar de haber estado, algunos de ellos, dedicados al cultivo de la caña de azúcar por 380 o más años. Son friables y de color pardo desde la superficie hasta profundidades mayores de 4 pies.

Los suelos de la serie Estación son derivados del material lavado de los suelos de la serie Catalina y sus asociados, los suelos rojos y purpúreos de la altura. Son por lo tanto, ligeramente o fuertemente ácidos y de color gris pardo. Son pobres en bases y algo inferiores a los de la serie Toa en alimentos.

Los suelos de la serie Viví son producto del material lavado de las colinas graníticas. Son grises, areniscos y muy ácidos. Los suelos de reacción ácida son generalmente pobres en bases comparados con los suelos de reacción alcalina. Los suelos Viví son más pobres en bases y alimentos que los Toa y Estación.

Los suelos de la serie San Antón se forman del material lavado de las series Descalabrado, Aguilita y sus asociados de la región árida. Estos suelos son alcalinos o calcáreos, friables, granulosos y de color oscuro. Con riego y abono producen rendimientos mayores de caña de azúcar que los suelos de la serie Toa.

La serie Altura se deriva del mismo material que la serie San Antón pero ocupa áreas que reciben un poco más de lluvia, y son por lo tanto de color más oscuro en la superficie. En sus condiciones naturales tienen mayor contenido de materia orgánica y alimentos que los San Antón. Con riego y abono las mejores áreas de estos suelos, deben producir los rendimientos mayores de caña de azúcar en la isla.

Desde el punto de vista físico y probablemente químico, los suelos de aluvión con buen drenaje son los mejores suelos de caña de azúcar en Puerto Rico porque tienen una topografía casi a nivel, buen drenaje, son friables, profundos, y casi ideales para lograr cosechas de producción máxima. Estos suelos pueden ser cultivados en su totalidad y permiten el uso de cualquier maquinaria agrícola moderna. El suelo superficial es suelto y poroso y fácil de cultivar a mano o con maquinaria. El agua penetra en ellos rápidamente, pero la cantidad de limo y arcilla del subsuelo es suficiente para retener grandes cantidades de agua. A pesar de que estos suelos contienen bastante materia orgánica y alimentos, los rendimientos en las cosechas aumentan considerablemente aplicando abonos y estiércol. Aunque estos suelos se adaptan a la diversificación de cosechas comerciales; más del 95 por ciento de ellos se siembran de caña de azúcar, la cosecha que corrientemente ha resultado ser de más provecho. Los rendimientos fluctúan entre 35 y 105 toneladas de caña por acre con 8 a 14 por ciento de sacarosa, siempre y cuando se abonen y rieguen propiamente.

Los suelos de aluvión de drenaje pobre incluyen 39 tipos y fases de las series Coloso, Fortuna, Martín Peña y Vega Baja, de la parte húmeda y semi-húmeda cerca de la costa occidental, norte y nordeste; las series Josefa, Irurena, Maunabo, Yabucoa y Talante, de la costa húmeda oriental; y las series Aguirre, Guánica y Vayas, de la costa árida del sur.

Todos los suelos de este grupo están a pocos pies sobre el nivel del mar; en muchos de ellos, el nivel freático está a un promedio menor de 24 pulgadas de la superficie. Muchas áreas son afectadas por inundaciones frecuentes. Son de relieve casi plano y son cubiertas por la acumulación lenta de sedimentos que bajan en las aguas de las montañas del interior hasta depositarse en esos sitios donde el agua permanece quieta; el proceso de sedimentación, por lo tanto, produce una textura pesada desde la superficie hasta grandes profundidades del subsuelo. Muchos de los suelos de este grupo están tan íntimamente asociados que no es posible tirar con precisión la línea de separación entre ellos.

La mayor parte de estos suelos ocurren en áreas bajas, de drenaje pobre o imperfecto, situadas entre los suelos de aluvión de buen

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drenaje y los suelos de los bajos costaneros. De 80 a 85 por ciento del área se dedica a la caña de azúcar; la B. H. 10 (12) es la variedad principal. El remanente de 15 a 20 por ciento se dedica a malojillo que se corta para llevar a las vaquerías o se usa para pastoreo de bueyes y ganado lechero.

La maquinaria que se usa para el cultivo de los tipos arenosos de estas tierras de drenaje pobre es la misma que se usa en los suelos de aluvión de buen drenaje, pero en los tipos de textura pesada, mucho del trabajo es manual, lo que aumenta el costo de producción. Si estas tierras pesadas se cultivan húmedas, el suelo se amasa y se forman grandes terrones. El cultivo mecánico requiere varias rastrilladas para romper los terrones; pero debido a los aguaceros torrenciales del trópico la lluvia penetra dentro de los terrones y ayuda a desmoronarlos.

El subsuelo de estos suelos es pesado, moteado de color ocre oscuro y gris; en algunas de las áreas de drenaje pobre las capas de subsuelo inferior son todas gris o azul-grisáceo. En muchos sitios el nivel freático se encuentra a tres pies de la superficie. Una proporción alta del área total de estos suelos de textura pesada necesita drenaje artificial. Esto se hace usualmente cavando algunas zanjas grandes y muchas pequeñas. El sistema de gran banco se usa para sembrar la caña. La B. H. 10 (12), hasta la fecha, es la mejor variedad cultivada comercialmente. En los años de sequía estas tierras pesadas, si son bien administradas, son más productivas que los suelos de aluvión de buen drenaje que no se riegan. Esto se debe a la capacidad que tiene el subsuelo pesado de absorber suficiente cantidad de agua para uso de las raíces en tiempo de sequía; el nivel alto del agua del subsuelo suplementa también este efecto. En tiempo de lluvia el drenaje adecuado es un problema; a veces se pierde mucha caña por el efecto de inundación; los rendimientos por lo tanto, son inferiores que los suelos de aluvión de buen drenaje. El arado profundo es momentáneamente efectivo debido a la consistencia plástica de la arcilla pesada y pegajosa que cementa las partículas.

La serie Coloso se deriva del material neutral y de textura fina que se lava de las series Múcara, Colinas y suelos asociados, residuales, productos de rocas volcánicas y calcáreas de grano fino. Comparativamente, podemos decir que los suelos de la serie Coloso pueden considerarse como los de la serie Toa de drenaje pobre. Son profundos, libres de piedra, ricos en fertilidad, neutrales y plásticos. Las características de la mayor parte de estos suelos son: textura pesada, alto nivel freático, superficie de color oscuro, y subsuelo veteado de gris, azul-grisáceo, y ocre oscuro.

La serie Fortuna es similar a la Coloso, pero como se deriva principalmente de los sedimentos lavados del suelo ácido Catalina y sus asociados, son más ácidos y oscuros. La relación entre las series Fortuna y Estación es idéntica a la del Coloso y Toa.

La serie Vega Baja ocupa una posición intermedia entre las llanuras costaneras y los suelos de aluvión, por lo tanto, posee características de ambos grupos. Estos suelos se componen de material sedimentario de color oscuro, medio plástico, ligeramente ácido, que descansa a cerca de 18 pulgadas de profundidad sobre material costanero plástico, fuertemente ácido, veteado de rojo, gris y amarillo. Son menos productivos que los suelos de las series Coloso y Fortuna, y rara vez se inundan.

Los suelos de la serie Martín Peña son similares a los Vega Baja, pero ocupan posiciones algo más bajas y son afectados con más frecuencia por inundaciones y próximo nivel freático; son menos productivos que los de las series Coloso y Vega Baja.

Las series Talante, Irurena, Yabucoa, Josefa y Maunabo, ocurren principalmente al sudeste de la isla en los valles enriquecidos por el material granítico lavado de las alturas adyacentes. Los suelos de las cinco series son similares en características; en algunos sitios donde el cambio entre ellos es muy gradual, las líneas de demarcación se han trazado más o menos arbitrariamente.

Durante la temporada excepcional de lluvias torrenciales muchos de estos suelos se inundan y la fuerza del agua que corre a través de los valles inundados, cambia el curso de las corrientes fluviales; ésto contribuye a mezclar el material del suelo y hace posible cambios de textura y series de suelos en algunos sitios. Los suelos de estos valles, dentro de 10 a 20 años, serán considerablemente diferentes a los que presenta el mapa de suelos. Los suelos que sufrirán más cambios son los que están adyacentes o cerca de las corrientes fluviales en los sitios altos de los valles.

Los suelos de la serie Talante se derivan del material granítico de grano grueso, por lo tanto, son friables, grises, y pobres en nutrimentos. La relación entre estos suelos y los de buen drenaje de la serie Viví es idéntica a la que tienen respectivamente las series Coloso y Fortuna con las series Toa y Estación.

Los suelos de la serie Irurena difieren de los de la serie Talante en el color pardo más oscuro de la superficie y en tener proporción algo mayor de material de textura fina en todos los horizontes y el nivel freático próximo a la superficie.

La serie Yabucoa difiere de la Irurena en tener un color más claro en la superficie y en ser de drenaje más pobre, especialmente en el subsuelo.

La serie Josefa tiene la misma relación con la serie Yabucoa que la que existe entre las series Talante y Viví, es decir, los suelos de la serie Josefa tienen drenaje más pobre y la superficie está veteada de color gris y pardo.

Los suelos de la serie Maunabo ocupan una posición intermedia entre los suelos de aluvíón de drenaje pobre y los suelos de los bajos costaneros. Tienen algunas características de los suelos de cada grupo, pero se parecen más a los suelos de las series Josefa y Yabucoa que a los de la serie Palmas Altas. Periódicamente son afectados por inundaciones que duran algún tiempo.

Los suelos de las series Vayas, Aguirre y Guánica, ocurren en los valles de las regiones áridas y semi-áridas, son por lo tanto, alcalinos de color oscuro, y ricos en alimentos. Estos suelos, bien administrados, son muy productivos; más que los otros suelos de este grupo. En algunos sitios el contenido perjudicial de sal es suficiente para hacer daño a las cosechas. Riego y drenaje adecuados son necesarios para sacar mejor provecho.

Podemos considerar que los suelos Vayas son suelos de la serie San Antón con drenaje pobre. Son de color pardo o gris pardo oscuro, granulosos, profundos, muy productivos; ocupan las áreas de topografía casi plana que están adyacentes o cerca del curso de las corrièntes fluviales y del mar. Están a pocos pies de altura sobre el nivel del mar; el nivel freático está relativamente próximo a la superficie.

La serie Aguirre de las regiones áridas se parece bastante en color, textura y características físicas a los de la serie Coloso de las regiones húmedas. Sin embargo, ella ha sido afectada más por depósitos de origen estuario y menos por depósitos de aluvión que la serie Coloso.

Los suelos de la serie Guánica son similares a los de la serie Aguirre con excepción de que tienen el nivel freático más próximo a la superficie y son más oscuros, algo más pesados y de drenaje más pobre.

SUELOS DE LOS BAJOS COSTANEROS

Los suelos bajos costaneros, de acuerdo con su vegetación, pueden agruparse en tres subdivisiones. La faja angosta del exterior incluye los suelos de buen drenaje dedicados a cocos y a hortalizas. La segunda subdivisión incluye los suelos de drenaje pobre dedicados al cultivo de la caña de azúcar y yerbas forrajeras. La tercera subdivisión incluye los suelos orgánicos de mal drenaje ocupados en su mayor parte por manglares.

Los terrenos de buen drenaje de los bajos costaneros incluyen las series de suelos denominadas: Cataño, Aguadilla, Palm Beach, playa, Meros, Jaucas y duna. Todos estos suelos son friables, de buen drenaje, pobres en fertilidad, muy arenosos, profundos, y de color gris o pardo. Las series Meros y Jaucas ocurren en la sección árida y son suelos calcáreos. Todos los otros suelos ocurren en áreas húmedas y son neutrales, alcalinos o calcáreos. Debido a su textura arenosa, fertilidad pobre, y permeabilidad excesiva, estos suelos se adaptan mejor al cultivo del coco y de frutos menores tales como batatas, yuca, maní y melones, que a caña y tabaco que requieren suelos de fertilidad rica y capacidad máxima para retener agua. Los frutos menores y los cocos dan cosechas más remunerativas cuando crecen en suelos arenosos que cuando crecen en suelos arcillosos pesados o que tengan drenaje deficiente. También los cocos crecen mejor y producen mayor rendimiento cuando crecen en los niveles bajos de la costa que en las alturas del interior. Los suelos en este grupo están muy cerca del mar para la producción de tabaco de buena calidad; son muy bajos y secos para el cafeto, y muchos no se adaptan al cultivo de piñas por ser muy alcalinos. La yerba de guinea, el algodón y las citrosas pueden crecer bien en las mejores áreas de estos suelos.

Mientras más árido es el clima y más arenosos son los suelos, los rendimientos de las cosechas son más bajos. Por lo tanto, los suelos Meros y Jaucas son menos productivos que los de textura similar en las series Cataño y Aguadilla. El tipo de suelo Cataño arena es menos productivo que el tipo Cataño arena lómica. La duna es menos productiva que cualquier otro tipo de suelo porque está compuesta de arena traída recientemente y continuamente del litoral inmediato.

La práctica agrícola general en estos suelos es sembrar palmas de coco a 40 pies de separación e intercalar entre ellas frutos menores u hortalizas. Arboles de toronja y la yerba de guinea se siembran en una pequeña proporción del área. Estas siembras, lo mismo que la de maní y algodón, podrían ampliarse si las condiciones económicas así lo permiten. La permeabilidad excesiva de estas tierras requiere periódicas aplicaciones pequeñas de abono para lograr los mejores rendimientos; pero la cantidad necesaria para obtener el beneficio neto mayor

depende, en gran parte, de condiciones económicas tales como el precio del abono y el valor de la cosecha.

Con excepción de algunos propietarios de fincas grandes dedicadas al cultivo del coco, la mayor parte de estas tierras se dividen en predios pequeños, densamente poblados, especialmente en las regiones húmedas. Probablemente cerca de 600 habitantes por milla cuadrada viven en los suelos de las series Cataño y Aguadilla. Aquí se encuentra un porciento mayor de negros y de bohíos que en cualquier otro distrito rural de la isla. El agua se obtiene de pozos cavados dentro de la arena hasta una profundidad de 6 a 9 pies.

Intimamente asociados con los suelos de buen drenaje en los bajos costaneros, pero por lo general ocupando áreas más al interior y adyacentes a los manglares, se encuentra la segunda subdivisión de los suelos de drenaje pobre. Aquí están representadas las series Palmas Altas, Piñones, Córcega y las fases de drenaje pobre de las series Cataño y Aguadilla; todos estos ocurren en la región húmeda. Las series Ursula, Serrano, Cintrona, y Meros arena, fase salina, ocurren en las regiones áridas de la costa sur. Estos suelos son casi llanuras a nivel que pueden estar anegadas algunos meses del año. Los de la región árida son calcáreos; muchas áreas están afectadas por concentraciones tóxicas de sales. La mayoría de estos suelos son arcillas plásticas pesadas o de textura limo-arcillosa lómica, que tienen una capacidad alta de retención de agua, pero que son difíciles para arar y proveerles avenamiento adecuado. La mayoría de las áreas en las regiones húmedas son ácidas.

La productividad de casi todas estas tierras depende de la efectividad de un sistema de drenaje artificial. Las áreas de buen drenaje se usan para caña de azúcar y producen de 30 a 40 toneladas de gran cultura cuando se siembran en gran-banco y se abonan adecuadamente. Las áreas que no son muy salinas o húmedas se usan ventajosamente para malojillo. Las áreas demasiado húmedas están en su mayor parte en manglares. Las áreas salinas están cubiertas de mangle, yerbas y juncos resistentes a la sal.

La mayor parte de la tierra, dentro del área que comprende extensiones amplias de los suelos de drenaje pobre, es propiedad de centrales azucareras y dueños de vaquerías. Muy poca gente vive en estas tierras, porque las áreas que no están bajo drenaje son muy húmedas e insalubres para los seres humanos y las áreas de buen drenaje se dedican a caña de azúcar, por lo tanto están desprovistas de casas de viviendas.

Los suelos orgánicos y de drenaje pobre, comprendidos en la tercera subdivisión de los bajos costaneros, se encuentran en franjas largas y angostas detrás de los suelos de buen drenaje. Aquí están los tipos de suelos clasificados como Tiburones muck, Saladar muck, fase poco-profunda, turba, Piñones arcilloso, fase subsuelo turboso, y Reparada arcilloso. En algunos sitios, estos suelos ocurren al borde de las aguas; están cubiertos por el agua en tiempo de marea alta y humedecidos en tiempo de marea baja. En otras palabras, están a nivel del mar o solamente a pocos pies sobre éste. Son oscuros, ácidos y limosos. Prácticamente todos los que no tienen drenaje adecuado contienen tal cantidad de sales que la vegetación está limitada a mangles y otras plantas resistentes a la sal.

Algunas áreas se han podido cultivar después de proveerlas con zanjas para el drenaje, diques y bombas costosas; aquí la caña de

azúcar es la cosecha principal, su rendimiento es de 30 á 40 toneladas de gran cultura por acre, pero el contenido de sacarosa es muy bajo comparado con la caña producida en los suelos minerales. El negocio principal en las áreas que no se pueden cultivar es hacer carbón de mangle.

Una gran proporción de estas tierras es propiedad del Gobierno Insular y es administrada por el Servicio Forestal Insular.

GLOSARIO

Este glosario contiene el equivalente en castellano de parte de la terminología técnica inglesa usada en este trabajo.[27]

Se propone que el suelo que se clasifica en inglés como "loam", y que en algunos países latinos ha sido denominado indebidamente, tierra franca o suelta, se le llame, suelo lómico o loam. "Loam texture" debe traducirse, textura o contextura lómica. La traducción que da el diccionario para loam es, marga. Este término es erróneo porque la marga es un suelo calcáreo. Se propone que "sheet erosion" se traduzca, erosión laminosa, y "gully erosion", erosión barrancosa. Al término "strip cropping" le llamamos, cosechando en fajas.

Terminología castellana	*Terminología inglesa*
Arena	Sand.
Arena lómica o suelo lómico arenoso	Loamy sand soil.
Arenoso al tacto	Gritty.
Aluvión en abanico	Alluvial fans.
Bajos costaneros	Coastal lowlands.
Bancales	Terracès.
Buena condición para el laboreo	Good tilth.
Capacidad del suelo para retener agua	Soil water-holding capacity.
Citrosas	Citrus.
Color ocre	Rust color.
Color oscuro	Dark color.
Color pardo	Brown color.
Corrientes fluviales (incluye ríos y quebradas)	Streams.
Corrientes fluviales intermitentes	Intermittent streams.
Cosechando en fajas	Strip cropping.
Desmoronar los terrones	To break the clods.
Drenado, avenado	Drained.
Drenaje, avenamiento	Drainage.
Duro	Hard.
Erosión barrancosa	Gully erosion.
Erosión laminosa	Sheet erosion.
Escarpado, empinado	Steep.
Fase en cerros	Hilly phase.
Fase erosiva	Eroded phase.
Fase poco-profunda	Shallow phase.
Fase rodante	Rolling phase.
Fase turbosa	Peaty phase.
Fase salina	Saline phase.
Frágil	Brittle.
Friable	Friable.
Granuloso, granular	Granular.
Grava de río o lavado de río	Riverwash.
Intercalar cosechas	Intercrop.
Juncos	Sedges.
Loam lime-arcilloso o suelo lime-arcilloso lómico	Silty clay loam soil.
Llano, plano, a nivel	Level surface.
Llanuras costaneras	Costal plains.
Llanuras interiores	Inner plains.

[27] La traducción ha sido hecha por Juan A. Bonnet, Jefe Sección de Suelos, Estación Experimental Agrícola de la Universidad de Puerto Rico, y revisada por Fernando A. Villamil, químico de dicha Sección.

Terminología castellana	*Terminología inglesa*
Malezas o matojos	Brush.
Mata	Shrub.
Moteado, veteado	Mottled.
Nivel freático	Water table.
Pegajoso	Sticky.
Pendiente, ladera, declive	Slope.
Pendiente lisa	Smooth slope.
Plantas halófilas o halofíticas	Halophytic vegetation.
Plantas mesofíticas	Mesophytic vegetation.
Plantas xerófilas o xerofíticas	Xerophytic vegetation.
Riolita	Rhyolite.
Se amasa; forma un amasijo	Becomes puddled.
Suelo arcilloso lómico o loam arcilloso	Clay loam soil.
Suelo arcilloso o arcilla	Clay soil.
Suelo arenoso lómico	Sandy loam soil.
Suelos de la altura	Soils of the uplands.
Suelo limo arcilloso	Silty clay soil.
Suelo lómico o loam	Loam soil.
Suelo pedrego arcilloso	Stony clay soil.
Tenaz	Stiff.
Terreno baldío	Wasteland.
Tobas	Tuffaceous rocks.
Turba	Peat.
Valles de aluvión	River flood plains.

PRODUCTIVITY RATINGS

Table 14 gives a rating of each soil type, soil phase, and miscellaneous land type according to its productivity for the crop or crops most generally grown. For convenience, the soil types are listed in alphabetical order.

TABLE 14.—*Productivity ratings of soils in Puerto Rico* (TABLA 14.—*Clasificación de los suelos de Puerto Rico a base de productividad*)

Soil type (Tipo de suelo)	Sugarcane (Caña de azúcar)	Tobacco (Tabaco)	Coffee (Café)	Grapefruit (Toronjas)	Pineapples (Piñas)	Bananas (Guineos)	Corn (Maíz)	Sweetpotatoes (Batatas)	Pigeonpeas (Gandules)	Beans (Habichuelas)	Yautia (Yautía)	Yucca (Yuca)	Yam or ñame (Ñame)	Coconuts (Cocos)	Cotton (Algodón)	Hay (Yerba de corte)	Pasture (Pasto)	General rating (Clasificación general)	Principal crops (Cultivos principales)
Aguadilla sandy loam (arenoso lómico).	30	--	--	90	60	40	15	100	80	60	40	60	30	100	90	--	45	6	Coconuts, grapefruit (Cocos, toronjas).
Aguadilla sandy loam, poorly drained phase (arenoso lómico, fase drenaje pobre).	--	--	--	--	--	--	--	[1] 60	--	--	45	--	--	80	--	[7] 10	40	7	Coconuts (Cocos).
Aguadilla loamy sand (arena lómica).	25	--	--	85	55	40	15	100	80	40	35	--	25	100	80	--	50	7	Do.
Aguadilla loamy sand, poorly drained phase (arena lómica, fase drenaje pobre).	[1] 30	--	--	--	--	--	--	60	--	--	40	--	--	80	--	[2] 10	40	7	Do.
Aguadilla sand (arena)	20	--	--	60	40	35	15	80	70	40	25	--	--	90	75	--	30	8	Do.
Aguilita clay (arcilloso)	--	--	--	--	--	35	5	5	5	5	15	--	--	--	--	--	10	10	Grass, brush (Yerba, maleza).
Aguilita stony clay (pedrego-arcilloso).	--	--	--	--	--	30	--	--	5	5	--	--	--	--	--	--	5	10	Brush (Maleza).
Aguilita stony clay, shallow phase (pedrego-arcilloso, fase poco-profunda).	--	--	--	--	--	30	--	--	--	--	--	--	--	--	--	--	5	10	Do.
Aguirre clay (arcilloso)	[3] 85	--	--	--	--	--	--	--	--	--	--	--	--	--	--	[4] 35	[4] 35	2	Sugarcane (Caña de azúcar).
Aguirre silt loam (limoso lómico)	[3] 90	--	--	--	--	--	--	--	--	--	--	--	--	--	--	[4] 35	[4] 35	2	Do.
Alonso clay (arcilloso)	45	30	95	[5] 70	55	70	15	40	30	30	55	25	60	--	--	--	30	5	Coffee (Café).
Alonso clay, smooth phase (arcilloso, fase lisa).	60	35	95	[5] 75	70	75	30	50	50	60	60	30	80	--	--	--	30	4	General farm crops (Cultivos generales).
Alonso clay, shallow phase (arcilloso, fase poco-profunda).	--	--	10	--	--	40	5	30	20	20	20	15	20	--	--	--	20	9	Pasture (Pasto).
Alonso clay, colluvial phase (arcilloso, fase coluvial).	45	[2] 40	100	[5] 90	[5] 65	80	5	45	50	60	65	30	80	--	--	--	30	4	Coffee, subsistence crops (Café, cultivos de subsistencia).
Alonso silty clay loam (limo-arcilloso lómico).	[2] 30	[2] 25	--	[1] 60	[1] 60	60	[2] 30	45	25	30	60	[2] 30	[1] 60	--	--	--	25	6	Pasture, subsistence crops (Pasto, cultivos de subsistencia).
Alonso silty clay loam, colluvial phase (limo-arcilloso lómico, fase coluvial).	[2] 60	[2] 40	--	[1] 70	[1] 70	[1] 75	[2] 35	50	[2] 55	[2] 65	65	[2] 30	[1] 60	--	--	--	30	5	Subsistence crops, pasture (Cultivos de subsistencia, pasto).
Altura clay (arcilloso)	[6] 140	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	Sugarcane (Caña de azúcar).
Altura silty clay (limo-arcilloso)	[6] 145	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	Do.
Altura silt loam (limoso lómico)	[6] 150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	Do.
Altura loam (lómico)	[6] 145	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	Do.
Altura loam, shallow phase (lómico, fase poco-profunda).	[6] 65	--	--	--	--	--	--	[2] 60	--	--	--	--	--	--	--	10	50	4	Do.
Amelia clay (arcilloso)	50	40	--	--	--	30	45	--	45	35	15	--	--	--	50	--	30	5	Sugarcane, pasture (Caña de azúcar, pasto).

Almirante clay (arcilloso)	50	40	----	60	70	60	35	50	40	40	60	25	55		----	---	25	5	Sugarcane, subsistence crops (Caña de azúcar, cultivos de subsistencia).
Almirante sandy clay (areno-arcilloso).	50	35	---	70	60	50	35	55	40	40	60	30	55	----	----	----	25	5	Do.
Almirante fine sandy loam (fino arenoso lómico).	40	30	----	80	50	50	35	75	40	40	60	30	40	----	60	----	20	6	Grapefruit, subsistence crops (Toronjas, cultivos de subsistencia).
Arcadia loam (lómico)	[7] 45	[2] 40	----	----	-	----	----	50	45	35	----	----	----	----	----	----	25	6	Sugarcane, pasture (Caña de azúcar, pasto).
Algarrobo fine sand (arena fina)	----	----	----	[2] 15	----	----	----	25	15	10		10	[2] 10	30	----	10	10	10	Pasture, idle (Pasto, barbecho).
Barrancas clay (arcilloso)	[3] 65	----	----	----	----	70	----	.	65	50	[2] 70	----	----	----	----	[2] 25	[2] 40	4	Sugarcane (Caña de azúcar).
Barrancas silty clay loam (limo-arcilloso lómico).	[3] 65	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	4	Do.
Bayamón clay (arcilloso)	50	50	----	60	85	65	50	50	40	40	65	45	60	----	----	----	35	5	Sugarcane, subsistence crops (Caña de azúcar, cultivos de subsistencia).
Bayamón sandy clay (areno-arcilloso).	50	50	----	65	90	65	50	50	40	40	65	45	60	----	----	----	35	5	Do.
Bayamón sandy clay loam (areno-arcilloso lómico).	50	50	----	75	90	60	50	70	45	50	65	50	60	----	----	----	35	5	Do.
Bayamón fine sandy loam (fino arenoso lómico).	25	30	----	90	----	[2] 60	5	100	40	40	55	25	40	[2] 70	[2] 65	----	25	6	Grapefruit, subsistence crops (Toronjas, cultivos de subsistencia).
Bayamón loamy fine sand (arena fina lómica).	20	20	----	100	----	55	5	100	40	40	50	25	40	[2] 75	[2] 60	----	20	6	Do.
Cabo Rojo clay (arcilloso)	40	[2] 45	----	----	[1] 60	35	45	----	30	20	25	30	[2] 40	----	----	----	35	7	Sugarcane, pasture (Caña de azúcar, pasto).
Cabo Rojo clay, rolling phase (arcilloso, fase rodante).	----	----	----	----	----	25	----	----	30	----	----	----	----	----	----	----	35	9	Pasture (Pasto).
Candelero clay (arcilloso)	50	[2] 55	----	----	----	25	----	[2] 25	40	40	65	30	[2] 40	----	----	----	35	5	Sugarcane (Caña de azúcar).
Candelero clay, shallow phase (arcilloso, fase poco-profunda).	45	[2] 45	-	----	----	20	----	[2] 20	40	40	45	25	[2] 35	----	----	----	35	6	Do.
Candelero sandy clay loam (areno-arcilloso lómico).	45	[2] 55	----	----	----	30	----	[2] 35	45	45	60	30	[2] 30	----	----	----	35	6	Do.
Candelero sandy clay loam, shallow phase (areno-arcilloso lómico, fase poco-profunda).	40	[2] 40	----	----	----	25	----	----	[2] 40	[2] 45	[2] 40	35	----	----	----	25	40	7	Do.
Candelero sandy clay loam, broken phase (areno-arcilloso lómico, fase quebrada).	----	----	----	----	----	20	----	----	----	----	[2] 30	----	----	----	----	25	30	10	Pasture (Pasto).
Candelero loam (lómico)	45	[2] 40	----	----	----	35	----	----	[2] 45	[2] 45	[2] 45	----	----	----	----	----	45	6	Sugarcane (Caña de azúcar).
Candelero loam, shallow phase (lómico, fase poco-profunda).	40	----	----	----	----	20	----	[2] 60	[2] 40	[2] 40	[2] 30	----	----	----	----	25	40	7	Do.
Candelero sandy loam (arenoso lómico).	40	[2] 35	----	----	----	30	----	[2] 65	[2] 35	[2] 35	----	[2] 35	[2] 30	----	----	----	40	6	Do.
Catalina clay (arcilloso)	50	[2] 25	70	[5] 70	75	70	15	50	30	30	60	30	40	----	----	15	30	5	Coffee, general crops (Café, cultivos generales).
Catalina clay, steep phase (arcilloso, fase escarpada).	----	[2] 15	20	----	[2] 20	30	10	40	20	20	45	10	----	----	----	10	25	7	Coffee, pasture (Café, pasto).
Catalina clay, level phase (arcilloso, fase plana).	65	30	75	[5] 80	85	75	15	40	25	25	65	75	85	----	----	20	30	4	General crops (Cultivos generales).
Catalina stony clay (pedrego-arcilloso).	[2] 45	30	20	----	----	70	----	40	10	20	55	10	----	----	----	----	30	6	Coffee (Café).

See footnotes at end of table.

TABLE 14.—*Productivity ratings of soils in Puerto Rico* (TABLA 14.—*Clasificación de los suelos de Puerto Rico a base de productividad*)—Con.

Soil type (Tipo de suelo)	Sugarcane (Caña de azúcar)	Tobacco (Tabaco)	Coffee (Café)	Grapefruit (Toronjas)	Pineapples (Piñas)	Bananas (Guineos)	Corn (Maíz)	Sweetpotatoes (Batatas)	Pigeonpeas (Gandules)	Beans (Habichuelas)	Yautia (Yautía)	Yuca (Yuca)	Yam or ñame (Ñame)	Coconuts (Cocos)	Cotton (Algodón)	Hay (Yerba de corte)	Pasture (Pasto)	General rating (Clasificación general)	Principal crops (Cultivos principales)
Catalina stony clay, steep phase (pedrego-arcilloso, fase escarpada).	-----	-----	10	-----	-----	30	-----	-----	-----	-----	40	-----	-----	-----	-----	-----	15	7	Coffee, pasture (Café, pasto).
Camagüey silty clay (limo-arcilloso).	75	[2]75	[2]80	[2]20	-----	[2]80	[2]100	40	100	80	75	45	[2]60	-----	-----	[2]60	75	3	Sugarcane (Caña de azúcar).
Camagüey clay loam (arcilloso lómico).	70	[2]70	[2]80	[2]30	-----	[2]70	[2]100	40	100	80	75	45	[2]60	-----	-----	[2]60	75	3	Do.
Cataño loamy sand (arena lómica)	-----	-----	-----	85	--	40	15	100	60	60	40	60	30	90	60	20	40	6	Peanuts, coconuts (Maní, cocos).
Cataño loamy sand, shallow phase (arena lómica, fase poco-profunda).	-----	-----	-----	60	-----	40	-----	95	60	60	40	60	25	80	60	20	40	7	Coconuts (Cocos).
Cataño loamy sand, poorly drained phase (arena lómica, fase drenaje pobre).	-----	-----	-----	-----	-----	-----	[2]5	-----	-----	-----	-----	-----	-----	-----	-----	15	50	10	Saltgrass (Yerba de vidrio (Sesuvium)).
Cataño sand (arena)	-----	-----	-----	70	-----	35	15	70	50	35	30	55	20	95	50	15	30	8	Coconuts (Cocos).
Cataño sand, poorly drained phase (arena, fase drenaje pobre).	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	15	50	10	Saltgrass (Yerba de vidrio (Sesuvium)).
Cayaguá sandy clay loam (areno-arcilloso lómico).	[2]45	70	-----	-----	-----	50	65	80	40	45	75	20	[2]35	[2]40	-----	35	30	6	Tobacco, subsistence crops (Tabaco, cultivos de subsistencia).
Cayaguá sandy clay loam, steep phase (areno-arcilloso lómico, fase escarpada).	-----	50	-----	-----	-----	50	30	55	40	35	[2]40	-----	-----	-----	-----	25	25	8	Tobacco, pasture (Tabaco, pasto).
Cialitos clay (arcilloso)	40	20	50	[2]60	[2]60	60	15	35	30	30	55	30	35	-----	-----	-----	30	7	Coffee, pasture (Café, pasto).
Cialitos clay, steep phase (arcilloso, fase escarpada).	-----	[2]15	50	-----	-----	55	-----	30	10	[2]10	30	15	20	-----	-----	-----	25	6	Coffee (Café).
Cialitos clay, eroded phase (arcilloso, fase erosiva).	[2]25	[2]20	20	-----	-----	50	[2]5	30	10	[2]10	30	-----	30	-----	-----	-----	5	9	Grass, idle (Yerba, barbecho).
Ciales clay loam (arcilloso lómico)	40	50	70	-----	-----	50	30	40	40	40	45	15	-----	-----	-----	-----	25	6	Coffee, tobacco (Café, tabaco).
Ciales clay loam, smooth phase (arcilloso lómico, fase lisa).	45	70	75	-----	-----	50	45	50	40	40	50	20	[2]35	-----	-----	-----	30	5	Tobacco, coffee (Tabaco, café).
Ciales loam (lómico)	35	[2]45	[2]60	-----	-----	50	15	25	40	35	[2]45	-----	-----	-----	-----	-----	20	7	Grass, sugarcane (Yerba, caña de azúcar).
Ciales loam, smooth phase (lómico, fase lisa).	40	[2]50	[2]70	-----	-----	50	50	30	40	45	[2]45	-----	-----	-----	-----	-----	20	6	Sugarcane, grass (Caña de azúcar, yerba).
Ciales loam, colluvial phase (lómico, fase coluvial).	50	70	70	-----	-----	50	60	40	50	50	50	-----	-----	-----	-----	-----	20	5	Do.
Cintrona clay (arcilloso)	[6]70	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	25	50	4	Do.

Cintrona silty clay loam (limo-arcilloso lómico).	[6] 70															25	50	4	Do.
Cintrona loam (lómico)	[6] 75							15								20	50	5	Do.
Coastal beach (playa)						40								70				10	Seagrapes, coconuts (Uvas de playa, cocos).
Colinas clay loam (arcilloso lómico).	60	60				40	45	20	90	90	50	15				40	40	4	Sugarcane, subsistence crops (Caña de azúcar, cultivos de subsistencia).
Colinas clay loam, steep phase (arcilloso lómico, fase escarpada).		[2] 40				35	5	10	[2] 40	[3] 50	[2] 25						25	8	Grass, subsistence crops (Yerba, cultivos de subsistencia).
Colinas stony clay loam (pedrego-arcilloso lómico).																		10	Trees (Arboles).
Colinas stony clay loam, steep phase (pedrego-arcilloso lómico, fase escarpada).																	5	10	Do.
Colinas fine sandy loam (fino arenoso lomico).	55	60				30	45	25	80	80	35	15		[2] 60			40	7	Subsistence crops, sugarcane (Cultivos de subsistencia, caña de azúcar).
Colinas stony loam (pedregoso lómico).	55	60				35	50	15	85	85	35	15		[2] 60			35	6	Do.
Coamo clay (arcilloso)	[6] 120	[2] 40				30	55	25	30	30					[2] 50		30	1	Sugarcane, pasture (Caña de azúcar, pasto).
Coamo clay, alluvial-fan phase (arcilloso, fase abanico aluvión).							55	25	30	30					[2] 50		30	1	Pasture (Pasto).
Coamo silty clay loam (limo-arcilloso lómico).	[6] 120	[2] 40				30	55	25	30	30					[2] 50		30	1	Sugarcane, grass (Caña de azúcar, yerba).
Coamo silty clay loam, rolling phase (limo-arcilloso lómico, fase rodante).	55	45				45	50	25	30	30					55		50	5	Subsistence crops, grass (Cultivos de subsistencia, yerba).
Coloso clay (arcilloso)	100															100	150	1	Sugarcane (Caña de azúcar).
Coloso clay, poorly drained phase (arcilloso, fase drenaje pobre).	90															90	150	2	Hay, sugarcane (Yerba de corte, caña de azúcar).
Coloso silty clay (limo-arcilloso)	105															100	150	1	Sugarcane (Caña de azúcar).
Coloso silty clay loam (limo-arcilloso lómico).	95															90	140	2	Do.
Coloso clay loam (arcilloso lómico)	95															95	150	2	Do.
Coloso silt loam (limoso lómico)	105															100	150	1	Do.
Coloso loam (lómico)	70															80	90	6	Hay, sugarcane (Yerba de corte, caña de azúcar).
Córcega sandy clay (areno-arcilloso).	75			[2] 60		50		[2] 50	70	70	80	40		[2] 85		80	60	3	Sugarcane (Caña de azúcar).
Córcega sandy clay, poorly drained phase (areno-arcilloso, fase drenaje pobre).	60							[2] 30			85			55		90	70	6	Hay, sugarcane (Yerba de corte, caña de azúcar).
Córcega sandy loam (arenoso lómico).	50			[2] 55		50		100	80	80	60	40		75		60	55	5	Coconuts, subsistence crops, peanuts (Cocos, cultivos de subsistencia, maní).
Córcega sandy loam, poorly drained phase (arenoso lómico, fase drenaje pobre).	55							30			70			60		65	60	5	Coconuts, grass (Cocos, yerba).
Coto clay (arcilloso)	[8] 80	45		[8] 50		55	50	50	50	50	40	50	[8] 150				50	3	Subsistence crops (Cultivos de subsistencia).

See footnotes at end of table.

TABLE 14.—*Productivity ratings of soils in Puerto Rico* (TABLA 14.—*Clasificación de los suelos de Puerto Rico a base de productividad*)—Con.

Soil type (Tipo de suelo)	Sugarcane (Caña de azúcar)	Tobacco (Tabaco)	Coffee (Café)	Grapefruit (Toronjas)	Pineapples (Piñas)	Bananas (Guineos)	Corn (Maíz)	Sweetpotatoes (Batatas)	Pigeonpeas (Gandules)	Beans (Habichuelas)	Yautia (Yautía)	Yucca (Yuca)	Yam or ñame (Ñame)	Coconuts (Cocos)	Cotton (Algodón)	Hay (Yerba de corte)	Pasture (Pasto)	General rating (Clasificación general)	Principal crops (Cultivos principales)
Coto clay, heavy phase (arcilloso, fase pesada).	[3] 75	45	25			55	50	55	50	50	40	50	[3] 160				50	3	Subsistence crops (Cultivos de subsistencia).
Coto sandy clay (areno-arcilloso)	[3] 75	45		[3] 60		55	50	55	50	50	40	50	[3] 180				50	3	Do.
Coto loamy sand (arena lómica)	20	20		[3] 80		50	15	60	40	40	30	40		40	60		30	4	Do.
Caguas clay (arcilloso)	55	50		30	55	50	30	25	40	40	40	30				60	50	5	Sugarcane, subsistence crops (Caña de azúcar, cultivos de subsistencia).
Caguas sandy clay loam (areno-arcilloso lómico).	40	50		40	[2] 40	50	30	30	40	40	30	30				40	40	6	Subsistence crops (Cultivos de subsistencia).
Corozo fine sand (arena fina)				[2] 15	[2] 30	20		25	10	10		10		15	40		10	10	Idle (Barbecho).
Daguao clay (arcilloso)	40	[2] 45				40	45	20	60	70	[2] 30	25					50	7	Grass, sugarcane (Yerba, caña de azúcar).
Daguao clay, steep phase (arcilloso, fase escarpada).							25	10	20	20							50	9	Grass (Yerba).
Daguao clay, colluvial phase (arcilloso, fase coluvial).	60						[2] 60	40	65	75	65	[2] 60	[2] 75			100	100	5	Sugarcane, grass (Caña de azúcar, yerba).
Descalabrado silty clay (limo-arcilloso).								10									25	10	Grass (Yerba).
Descalabrado silty clay, eroded phase (limo-arcilloso, fase erosiva).	15					35	25	15	40	40	15	20					25	9	Subsistence crops, pasture (Cultivos de subsistencia, pasto).
Descalabrado silty clay, rolling phase (limo-arcilloso, fase rodante).							5	10	20	20							50	10	Grass (Yerba).
Descalabrado silty clay, shallow phase (limo-arcilloso, fase poco-profunda).								5	15	15							50	10	Do.
Dominguito clay (arcilloso)	65	[2] 55	[2] 70		[2] 60	80	45	45	35	30	65	80	100			60	70	4	Sugarcane (Caña de azúcar).
Dune sand (duna)						25								30				10	Seagrapes, idle (Uvas de playas, barbecho).
Espinosa clay (arcilloso)	55	45		50	70	60	35	50	40	40	60	35	85				55	5	Sugarcane, subsistence crops (Caña de azúcar, cultivos de subsistencia).
Espinosa sandy clay (areno-arcilloso).	50	40		50	75	60	35	50	40	40	60	35	85				55	5	Do.
Espinosa sandy loam (arenoso lómico).	30	30		60		50	15	65	40	40		20			[2] 60		50	6	Sugarcane, grapefruit (Caña de azúcar, toronjas).
Espinosa loamy sand (arena lómica).	20	20		80		50	5	70	40	40		20		45	[2] 60		50	6	Grapefruit, subsistence crops (Toronjas, cultivos de subsistencia).
Estación silty clay (limo-arcilloso)	75	[2] 85	60			[1] 75	[2] 95	[2] 60	[2] 90	[2] 90	[2] 95	[2] 80	[2] 120			100	[2] 100	3	Sugarcane (Caña de azúcar).
Estación clay loam (arcilloso lómico).	70	[2] 85	60			[2] 90	[2] 90	[2] 60	[2] 90	[2] 90	[2] 95	[2] 80	[2] 120			100	[2] 100	3	Do.

Estación silt loam (limoso lómico)	80	[2] 90	70			[2] 95	90	[2] 60	[2] 90	[2] 90	[2] 95	[2] 80	[2] 120			100	[2] 100	3	Do.
Estación silt loam, low-bottom phase (limoso lómico, fase fondo bajo).																120	150	10	Grass (Yerba).
Estación loam (lómico)	70	[2] 90	[2] 80			[2] 85	[2] 95	[2] 75	[2] 85	[2] 85	[2] 80	[2] 90	[2] 100			110	60	3	Sugarcane (Caña de azúcar).
Estación sandy loam (arenoso lómico).	35	[2] 75	[2] 80			70	75	100	70	70	50	75	60			80	50	5	Sugarcane, subsistence crops, tobacco (Caña de azúcar, cultivos de subsistencia, tabaco).
Ensenada clay (arcilloso)						5	5	5	5								5	10	Brush, grass (Maleza, yerba).
Ensenada clay, shallow phase (arcilloso, fase poco-profunda).																	5	10	Brush (Maleza).
Fajardo clay (arcilloso)	60			[2] 40	[2] 40	[2] 60	[2] 45	[2] 40	[2] 40	[2] 40	[2] 60	[2] 60	[2] 95			70	80	4	Sugarcane (Caña de azúcar).
Fajardo clay, gray phase (arcilloso, fase gris).	55					[2] 50	[2] 45	[2] 35	[2] 35	[2] 35	[2] 70	[2] 60	[2] 85			75	85	5	Do.
Fajardo clay, steep phase (arcilloso, fase escarpada).						[2] 30		[2] 30	[2] 30	[2] 30	[2] 30	[2] 50	[2] 35				65	8	Grass (Yerba).
Fé clay (arcilloso)	[3] 80																[4] 35	3	Sugarcane, grass (Caña de azúcar, yerba).
Fé clay, imperfectly drained phase (arcilloso, fase drenaje imperfecto).	[3] 90																[4] 35	3	Do.
Fortuna clay (arcilloso)	75															100	100	3	Sugarcane (Caña de azúcar).
Fortuna clay, poorly drained phase (arcilloso, fase drenaje pobre).	75															100	100	3	Do.
Fortuna silty clay loam (limo-arcilloso lómico).	85															100	100	2	Do.
Fortuna clay loam (arcilloso lómico).	85															100	100	2	Do.
Fraternidad clay (arcilloso)	[6] 90	45				40	75	20	40	40	15				45	20	40	2	Do.
Fraternidad clay, shallow phase (arcilloso, fase poco-profunda).		35					50										25	8	Grass (Yerba).
Fraternidad clay, imperfectly drained phase (arcilloso, fase drenaje imperfecto).	40										50					20	70	6	Sugarcane, grass (Caña de azúcar, yerba).
Fraternidad clay, colluvial phase (arcilloso, fase coluvial).		40					75	25	40	45	15				20		35	7	Grass, subsistence crops (Yerba, cultivos de subsistencia).
Fraternidad clay loam (arcilloso lómico).		35					85										30	6	Grass, sugarcane (Yerba, caña de azúcar).
Guánica clay (arcilloso)	[6] 80															70	85	3	Sugarcane, grass (Caña de azúcar, yerba).
Guayama clay (arcilloso)	[2] 15						[2] 35	15									25	10	Grass (Yerba).
Guayama clay, colluvial phase (arcilloso, fase coluvial).	[6] 115	50					85	25	40	45					20		40	3	Sugarcane, grass (Caña de azúcar, yerba).
Guayabo fine sand (arena fina)		[2] 30		[2] 40		[2] 50	35	65	20	20		35		65	40		25	8	Subsistence crops, cotton (Cultivos de subsistencia, algodón).
Guayabo fine sand, shallow phase (arena fina, fase poco-profunda).	25	45		[2] 45	[2] 65	60	40	75	35	35	[2] 10	40		[2] 60	60		50	6	Do.
Humacao clay (arcilloso)	60	[2] 60		[2] 55	[2] 60											85	80	4	Sugarcane (Caña de azúcar).
Humacao clay loam (arcilloso lómico).	55	[2] 60		[2] 55	[2] 60											85	80	5	Do.

See footnotes at end of table.

TABLE 14.—*Productivity ratings of soils in Puerto Rico* (TABLA 14.—*Clasificación de los suelos de Puerto Rico a base de productividad*)—Con.

Soil type (Tipo de suelo)	Sugarcane (Caña de azúcar)	Tobacco (Tabaco)	Coffee (Café)	Grapefruit (Toronjas)	Pineapples (Piñas)	Bananas (Guineos)	Corn (Maíz)	Sweetpotatoes (Batatas)	Pigeonpeas (Gandules)	Beans (Habichuelas)	Yautia (Yautía)	Yucca (Yuca)	Yam or ñame (Ñame)	Coconuts (Cocos)	Cotton (Algodón)	Hay (Yerba de corte)	Pasture (Pasto)	General rating (Clasificación general)	Principal crops (Cultivos principales)
Humacao loam (lómico)	55	[2] 60	65	[2] 60	[2] 55	60	----	----	----	----	----	----	----	----	----	85	80	5	Sugarcane (Caña de azúcar).
Humacao sandy loam (arenoso lómico).	35	----	----	[2] 65	[2] 50	----	----	----	----	----	----	----	----	----	----	85	80	6	Sugarcane, tobacco (Caña de azúcar, tabaco).
Irurena clay loam (arcilloso lómico).	75	----	----	----	----	----	----	----	----	----	120	----	----	----	----	100	100	3	Sugarcane (Caña de azúcar).
Irurena loam (lómico)	70	----	----	----	----	----	----	----	----	----	120	----	----	----	----	100	100	3	Do.
Islote clay loam (arcilloso lómico)	65	[2] 50	----	80	----	60	50	95	65	60	70	60	60	[2] 85	[2] 60	----	40	4	Sugarcane, subsistence crops (Caña de azúcar, cultivos de subsistencia).
Islote sandy loam (arenoso lómico)	60	[2] 50	----	90	----	55	40	100	65	60	60	50	60	90	[2] 50	----	40	4	Grapefruit, subsistence crops (Toronjas, cultivos de subsistencia).
Islote sandy loam, imperfectly drained phase (arenoso lómico, fase drenaje imperfecto).	55	----	----	[2] 20	----	30	40	80	----	----	75	----	----	90	----	40	55	4	Sugarcane (Caña de azúcar).
Islote sand (arena)	----	30	----	----	----	55	10	60	35	35	----	20	----	45	[2] 60	----	25	5	Subsistence crops (Cultivos de subsistencia).
Islote loamy sand (arena lómica)	[2] 20	30	----	----	----	50	----	75	30	30	----	20	----	55	[2] 60	----	25	5	Do.
Jácana clay (arcilloso)	[2] 15	----	----	----	----	----	30	25	20	20	----	----	----	----	20	----	35	8	Grass (Yerba).
Jaucas sand (arena)	----	----	----	----	----	----	----	30	----	----	----	15	----	50	----	----	----	10	Coconuts, idle (Cocos, barbecho).
Jayuya silty clay loam (limo-arcilloso lómico).	45	50	60	----	----	65	35	50	40	40	30	[2] 30	40	----	----	20	25	6	Tobacco, coffee, sugarcane (Tabaco, cafe, caña de azúcar).
Jayuya silty clay loam, steep phase (limo-arcilloso lómico, fase escarpada).	40	40	50	----	----	60	30	45	30	35	25	----	----	----	----	10	25	7	Coffee (Café).
Josefa clay (arcilloso)	70	----	----	----	----	----	----	----	----	----	----	----	----	----	----	90	95	4	Sugarcane (Caña de azúcar).
Josefa clay loam (arcilloso lómico)	75	----	----	----	----	----	----	----	----	----	----	----	----	----	----	90	95	3	Do.
Juana Díaz clay loam (arcilloso lómico).	----	----	----	----	----	----	----	30	----	----	----	----	----	----	----	----	40	8	Grass (Yerba).
Juana Díaz silty clay (limo-arcilloso).	40	40	----	----	----	----	50	35	----	----	----	----	----	----	[2] 45	5	45	6	Sugarcane, grass (Caña de azúcar, yerba).
Juncos clay (arcilloso)	60	70	[2] 60	----	----	[2] 70	65	35	70	80	50	35	----	----	----	20	60	4	Sugarcane, tobacco, subsistence crops (Caña de azúcar, tabaco, cultivos de subsistencia).
Lajas clay (arcilloso)	----	[2] 15	15	----	----	30	----	20	15	15	15	----	----	----	----	----	25	10	Trees (Arboles).
Lajas clay, rolling phase (arcilloso, fase rodante).	----	[2] 25	25	----	----	35	----	20	25	25	25	----	----	----	----	----	50	10	Do.
Lares clay (arcilloso)	[2] 75	50	65	[5] 75	75	70	50	50	50	50	65	40	100	----	----	30	65	3	Coffee, subsistence crops, sugarcane (Café, cultivos de subsistencia, caña de azúcar).

Lares clay, red-subsoil phase (arcilloso, fase subsuelo rojo).	[2] 75	[2] 45	45	---	[2] 65	70	50	50	50	50	60	[2] 45	100	---	---	30	65	3	Sugarcane, coffee (Caña de azúcar, café).
Lares clay, steep phase (arcilloso, fase escarpada).	---	---	40	---	---	60	---	30	[2] 30	[2] 30	[2] 40	[2] 30	[2] 80	---	---	---	50	8	Grass (Yerba).
Lares silty clay loam (limo-arcilloso lómico).	[2] 75	50	60	---	[1] 60	70	50	50	50	50	65	[2] 45	100	---	---	30	65	3	Coffee, sugarcane (Café, caña de azúcar).
Lares clay loam (arcilloso lómico)	70	50	60	---	[1] 60	70	40	50	50	50	65	[2] 45	100	---	---	30	65	4	Sugarcane (Caña de azúcar).
Lares sandy loam (arenoso lómico)	60	45	---	80	[1] 55	65	35	50	50	50	55	40	95	---	---	25	60	4	Subsistence crops, grapefruit (Cultivos de subsistencia, toronjas).
Las Piedras clay loam (arcilloso lómico).	60	75	---	[2] 70	[1] 70	65	70	60	40	40	45	35	---	[2] 60	---	30	65	4	Tobacco, sugarcane (Tabaco, caña de azúcar).
Las Piedras clay loam, steep phase (arcilloso lómico, fase escarpada).	---	50	---	---	---	55	---	50	---	---	---	---	---	---	---	---	60	8	Grass (Yerba).
Las Piedras loam (lómico)	65	70	---	[2] 75	[1] 70	60	70	60	40	40	40	35	---	[2] 65	---	30	65	4	Tobacco, sugarcane (Tabaco, caña de azúcar).
Llave loam (lómico)	[7] 40	[2] 35	---	---	---	55	40	50	45	35						---	55	6	Sugarcane (Caña de azúcar).
Llave sandy loam (arenoso lómico)	[7] 35	[2] 35	---	---	---	55	50	50	45	35	---	---	---	---	---	---	55	6	Do.
Los Guineos clay (arcilloso)	---	---	55	---	[1] 55	65	---	40	10	10	40	---	---	---	---	20	20	8	Coffee, trees (Café, árboles).
Los Guineos clay, smooth phase (arcilloso, fase lisa).	---	25	55	---	[1] 65	75	10	40	25	25	50		35	---	---	35	20	7	Do.
Mabí clay (arcilloso)	70	[2] 85	[2] 65	---	---	[2] 95	[2] 90	[2] 50	[2] 90	[2] 70	[2] 95	---	100+	---	---	85	120	3	Sugarcane (Caña de azúcar).
Mabí clay, flat phase (arcilloso fase chata).	75	[2] 60	---	---	---	70	---	40	80	65	100	---	---	---	---	90	120	3	Do.
Machete clay (arcilloso)	[6] 95	55	---	---	---	---	---	---	---	---	---	---	---	---	---	---	35	1	Do.
Machete clay loam (arcilloso lómico).	[6] 110	[2] 55	---	---	---	---	---	---	---	---	---	---	---	---	---	---	35	1	Do.
Machete loam (lómico)	55	[2] 50	---	---	---	55	50	35	50	50	45	---	---	---	---	---	50	2	Do.
Machete loam, steep phase (lómico, fase escarpada).	---	---	---	---	---	30	---	---	---	---	---	---	---	---	---	---	55	8	Grass (Yerba).
Matanzas clay (arcilloso)	[8] 70	55	---	[8] 60		75	65	25	80	30	40	50	[8] 180	---	---	---	35	4	Subsistence crops (Cultivos de subsistencia).
Matanzas sandy clay (areno-arcilloso).	[8] 75	55	---	[8] 65	---	75	65	35	80	30	40	55	[8] 180	---	---	---	35	3	Do.
Maleza fine sandy loam (fino arenoso lómico).	40	40	---	[8] 90	---	70	35	100	45	35	---	35	---	70	60	---	30	6	Do.
Maleza loamy sand (arena lómica)	35	30	---	[8] 95	---	70	30	100	45	35	---	30	---	60	[2] 50	---	30	7	Do.
Maunabo clay (arcilloso)	70	---	---	---	---	---	---	---	---	---	---	---		---	---	90	90	3	Sugarcane, rice (Caña de azúcar, arroz).
Maunabo silty clay loam (limo-arcilloso lómico).	75	---	---	---	---	---	---	---	---	---	---	---	---	---	---	90	90	3	Sugarcane (Caña de azúcar).
Maunabo clay loam (arcilloso lómico).	75	---	---	---	---	---	---	---	---	---	---	---	---	---	---	90	90	3	Do.
Maunabo loam (lómico)	70	---	---	---	---	---	---	---	---	---	---	---	---	---	---	85	90	3	Do.
Mayo loam (lómico)	50	---	---	---	---	50	50	100	50	40	---	50	45	---	---	---	70	6	Subsistence crops (Cultivos de subsistencia).
Mayo clay loam (arcilloso lómico)	70	---	---	---	---	50	60	80	50	40		50	45	---	---	---	70	6	Do.
Martín Peña clay (arcilloso)	70	---	---	---	---	---	---	---	---	[1] 100	[1] 100		---	---	---	100	90	4	Sugarcane (Caña de azúcar).
Martín Peña sandy clay loam (areno-arcilloso lómico).	65	---	---	---	---	---	---	---	---	[1] 100	[1] 95	---	---	---	---	90	85	4	Do.

See footnotes at end of table.

TABLE 14.—*Productivity ratings of soils in Puerto Rico* (TABLA 14.—*Clasificación de los suelos de Puerto Rico a base de productividad*)—Con.

Soil type (Tipo de suelo)	Sugarcane (Caña de azúcar)	Tobacco (Tabaco)	Coffee (Café)	Grapefruit (Toronjas)	Pineapples (Piñas)	Bananas (Guineos)	Corn (Maíz)	Sweetpotatoes (Batatas)	Pigeonpeas (Gandules)	Beans (Habichuelas)	Yautia (Yautía)	Yucca (Yuca)	Yam or ñame (Ñame)	Coconuts (Cocos)	Cotton (Algodón)	Hay (Yerba de corte)	Pasture (Pasto)	General rating (Clasificación general)	Principal crops (Cultivos principales)
Malaya clay (arcilloso)	[2] 30	[2] 30	[2] 80	--	--	60	25	40	45	40	45	[2] 20	--	--	--	--	30	7	Subsistence crops, grass (Cultivos de subsistencia, yerba).
Malaya clay, smooth phase (arcilloso, fase lisa).	[2] 65	[2] 45	[2] 100	[5] 80	[2] 75	80	45	50	70	85	60	30	60	--	--	--	35	4	Subsistence crops (Cultivos de subsistencia).
Mercedita clay (arcilloso)	[3] 80	--	--	--	--	--	--	[3] 35	--	--	--	--	--	--	--	[4] 40	[4] 40	2	Sugarcane (Caña de azúcar).
Meros sand (arena)	--	--	--	--	--	--	--	55	35	--	--	35	--	55	--	--	15	10	Coconuts, seagrapes (Cocos, uvas de playas).
Meros sand, saline phase (arena, fase salina).	--	--	--	--	--	--	--	15	--	--	--	--	--	--	--	--	20	10	Grass (Yerba).
Mariana clay loam (arcilloso lómico).	20	35	--	--	75	40	25	20	25	30	--	--	--	--		--	15	7	Pineapples, grass (Piñas, yerba).
Moca clay (arcilloso)	65	60	65	[2] 50	[2] 70	80	45	40	35	35	65	40	100	--	--	50	70	5	Sugarcane (Caña de azúcar).
Moca silty clay loam (limo-arcilloso lómico).	65	60	65	[2] 55	75	80	50	40	35	35	65	40	100	--	--	50	70	5	Do.
Moca silty clay loam, steep phase (limo-arcilloso lómico, fase escarpada).	--	--	50	--	--	60	50	30	35	35	65	--	--	--	--	--	70	8	Coffee (Café).
Moca loam (lómico)	60	65	65	[2] 70	[2] 70	80	50	50	35	35	60	45	[2] 90	--	--	50	65	6	Subsistence crops (Cultivos de subsistencia).
Múcara silty clay loam (limo-arcilloso lómico).	30	45	[2] 50	--	--	50	45	20	60	75	35	25	[2] 10	--	--	--	50	7	Tobacco, subsistence crops (Tabaco, cultivos de subsistencia).
Múcara silty clay loam, shallow phase (limo-arcilloso lómico, fase poco-profunda).	--	[2] 20	--	--	--	30	--	[2] 15	[2] 15	[2] 15	20	--	[2] 5	--	--	--	20	8	Subsistence crops, grass (Cultivos de subsistencia, yerba).
Múcara silty clay loam, steep phase (limo-arcilloso lómico, fase escarpada).	--	30	10	--	--	35	10	[2] 15	25	25	25	--	[2] 5	--	--	--	25	8	Grass, subsistence crops, tobacco (Yerba, cultivos de subsistencia, tabaco).
Múcara silt loam (limoso lómico)	20	[2] 40	[2] 50	--	--	45	35	25	55	70	25	20	[2] 10	--	--	--	45	8	Subsistence crops (Cultivos de subsistencia).
Múcara silt loam, steep phase (limoso lómico, fase escarpada).	--	[2] 25	[2] 50	--	--	50	--	15	25	25	20	--	--	--	--	--	25	9	Grass, subsistence crops (Yerba, cultivos de subsistencia).
Naranjito silty clay loam (limo-arcilloso lómico).	25	40	45	--	--	55	30	20	50	50	20	25	[2] 15	--	--	--	25	8	Subsistence crops (Cultivos de subsistencia).
Naranjito silty clay loam, smooth phase (limo-arcilloso lómico, fase lisa).	30	40	55	--	--	60	25	20	50	50	20	25	--	--	--	--	35	7	Tobacco, subsistence crops (Tabaco, cultivos de subsistencia).
Naranjito silty clay loam, steep phase (limo-arcilloso lómico, fase escarpada).	--	20	50	--	--	35	--	10	30	--	--	--	--	--	--	--	25	8	Grass, subsistence crops (Yerba, cultivos de subsistencia).

Naranjito silty clay loam, colluvial phase (limo-arcilloso lómico, fase coluvial).	35	[2] 55	[2] 60			[2] 65	30	25	[2] 55	[2] 50						30	45	6	Sugarcane, tobacco (Caña de azúcar, tabaco).
Nipe clay (arcilloso)	[2] 20		[2] 5			[2] 30	[2] 30		[2] 25	[2] 20							5	9	Trees (Arboles).
Pandura sandy clay loam (areno-arcilloso lómico).		45	[2] 50			40	30	35	35	25	30						25	7	Grass, tobacco (Yerba, tabaco).
Pandura sandy clay loam, smooth phase (areno-arcilloso lómico, fase lisa).		50	[2] 50			50	30	45	40	35	45	40	45				25	6	Tobacco, grass (Tabaco, yerba).
Pandura loam (lómico)		45	[2] 50			35	30	40	35	25	30						25	7	Grass, tobacco (Yerba, tabaco).
Pandura loam, smooth phase (lómico, fase lisa).		50	[2] 50			50	30	45	40	35	45	40	40				25	6	Tobacco, grass (Tabaco, yerba).
Paso Seco clay (arcilloso)	60						95								40	40	50	1	Sugarcane, corn (Caña de azúcar, maíz).
Paso Seco silty clay (limo-arcilloso).	[6] 135																	1	Sugarcane (Caña de azúcar).
Paso Seco silty clay loam (limo-arcilloso lómico).	[6] 135																	1	Do.
Paso Seco silt loam (limoso lómico).	[6] 130																	1	Do.
Paso Seco loam (lómico)	[5] 120							[2] 95										1	Do.
Peat (turba)	[9] 40															[2] 80	[9] 80	10	Mangroves (Mangle).
Peat, shallow phase (turba, fase poco-profunda).																[2] 80	80	10	Do.
Piñones clay (arcilloso)	[2] 60															100	150	5	Sugarcane, hay (Caña de azúcar, yerba de corte).
Piñones clay, peaty-subsoil phase (arcilloso, fase subsuelo turboso).	[2] 55															20	50	9	Mangroves (Mangle).
Piñones silty clay (limo-arcilloso).	70															100	150	3	Sugarcane, mangroves (Caña de azúcar, mangle).
Piñones sandy clay loam (areno-arcilloso lómico).	[2] 55															30	50	4	Sugarcane (Caña de azúcar).
Palmas Altas clay (arcilloso)	75															100	150	3	Sugarcane, hay (Caña de azúcar, yerba de corte).
Palmas Altas silty clay (limo-arcilloso).	70															100	150	3	Do.
Palmas Altas sandy clay loam (areno-arcilloso lómico).	55							85			65					85	100	5	Do.
Palmas Altas loam (lómico)	60							80								90	90	4	Sugarcane (Caña de azúcar).
Palmas Altas silty clay loam (limo-arcilloso lómico).	75															100	150	2	Do.
Ponceña clay (arcilloso)	[6] 125					65	[2] 90										35	1	Do.
Ponceña clay, eroded phase (arcilloso, fase erosiva).	[8] 60					60	[2] 85										35	3	Do.
Portugués clay (arcilloso)	[6] 100					65	90										35	2	Do.
Palm Beach sand (arena)						30		30	30	30				60			30	10	Coconuts (Cocos).
Plata clay (arcilloso)	55	[2] 50				65	[2] 45	[2] 20	60	60	[2] 30						30	5	Coffee, sugarcane (Café, caña de azúcar).
Plata clay, mixed phase (arcilloso, fase mixta).	[2] 40	50	60			70	50	20	60	60	[2] 30						30	5	Sugarcane (Caña de azúcar).

See footnotes at end of table.

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TABLE 14.—*Productivity ratings of soils in Puerto Rico* (TABLA 14.—*Clasificación de los suelos de Puerto Rico a base de productividad*)—Con.

Soil type (Tipo de suelo)	Sugarcane (Caña de azúcar)	Tobacco (Tabaco)	Coffee (Café)	Grapefruit (Toronjas)	Pineapples (Piñas)	Bananas (Guineos)	Corn (Maíz)	Sweetpotatoes (Batatas)	Pigeonpeas (Gandules)	Beans (Habichuelas)	Yautía (Yautía)	Yucca (Yuca)	Yam or ñame (Ñame)	Coconuts (Cocos)	Cotton (Algodón)	Hay (Yerba de corte)	Pasture (Pasto)	General rating (Clasificación general)	Principal crops (Cultivos principales)
Picacho stony clay loam (pedrego-arcilloso lómico).			35			35					[2] 45						20	10	Trees, coffee (Arboles, café).
Pozo Blanco clay (arcilloso)		40				15	60	25	45	40					[2] 35		35	2	Corn, subsistence crops (Maíz, cultivos de subsistencia).
Pozo Blanco clay loam (arcilloso lómico).		40				20	60	25	45	40				[2] 55	[2] 35		35	2	Do.
Reparada clay (arcilloso)																		10	Mangroves (Mangle).
Resolución clay loam (arcilloso lómico).	[7] 50					[2] 50												3	Sugarcane (Caña de azúcar).
Río Piedras clay (arcilloso)	50		60	[2] 30	[2] 30	70	[2] 45	25	40	40	[2] 35		40				25	5	Do.
Río Piedras silty clay loam (limo-arcilloso lómico).	45					[2] 70	[2] 45	[2] 25	[2] 40	[2] 40	[2] 30						25	5	Do.
Riverwash (lavado de río)																		10	Idle (Barbecho).
Río Cañas clay (arcilloso)	55	40				30	45	35	35	35					40		35	4	Sugarcane, grass (Caña de azúcar, yerba).
Río Arriba clay (arcilloso)	65	50	65		[1] 75	80	45	40	35	35	65		[2] 100			50	70	4	Sugarcane (Caña de azúcar).
Río Lajas sand (arena)	[2] 20	20		[2] 90		40	10	90	40	40		20		40	[2] 60		20	6	Subsistence crops (Cultivos de subsistencia).
Río Lajas sand, hardpan phase (arena, fase pan duro).	[2] 20	20		[2] 60		40	10	90	40	40		20		40	[1] 60		20	6	Do.
Rosario silty clay (limo-arcilloso)			[2] 15			15											5	10	Trees (Arboles).
Rosario silty clay, smooth phase (limo-arcilloso, fase lisa).						5											5	10	Grass, trees (Yerba, árboles).
Rough stony land (tierra quebrada pedregosa).			20			55					[2] 45						[2] 10	10	Trees (Arboles).
Sabana silty clay loam (limo-arcilloso lómico).	25	40	[2] 45			55	30	25	55	65	20	25					45	8	Subsistence crops (Cultivos de subsistencia).
Sabana silt loam (limoso lómico)	25	40	[2] 45			55	30	25	55	65	20	25					45	8	Do.
Saladar muck (muck)																		10	Trees (Arboles).
Saladar muck, shallow phase (muck, fase poco-profunda).																		10	Do.
Sabana Seca clay (arcilloso)	50	[1] 50		[2] 35	[2] 55	50	35	35	40	40	40	30	[2] 40			40	50	5	Sugarcane (Caña de azúcar).
Sabana Seca sandy clay loam (areno-arcilloso lómico).	40	[2] 50		40	40	50	35	50	40	40	30	30	[2] 30		80		40	6	Subsistence crops, pineapples (Cultivos de subsistencia, piñas).
San Antón clay (arcilloso)	[6] 110																	1	Sugarcane (Caña de azúcar).
San Antón silty clay (limo-arcilloso).	[6] 150																	1	Do.

San Antón silty clay, shallow phase (limo-arcilloso, fase poco-profunda).	[6] 70																	4	Do.
San Antón silty clay loam (limo-arcilloso lómico).	[6] 140																	1	Do.
San Antón clay loam (arcilloso lómico).	[6] 140																	1	Do.
San Antón silt loam (limoso lómico).	[6] 145																	1	Do.
San Antón silt loam, shallow phase (limoso lómico, fase poco-profunda).	[6] 60																	4	Do.
San Antón loam (lómico)	[6] 140							[2] 75										1	Do.
San Antón loam, shallow phase (lómico, fase poco-profunda).	[6] 50							[2] 70									30	5	Sugarcane, grass (Caña de azúcar, yerba).
San Antón fine sandy loam (fino arenoso lómico).	[6] 65							[2] 80										4	Sugarcane (Caña de azúcar).
San Germán clay (arcilloso)			25			[2] 25		25	[2] 15	[2] 20							10	10	Trees (Arboles).
Santa Isabel clay (arcilloso)	[6] 115																	1	Sugarcane (Caña de azúcar).
Santa Isabel silty clay loam (limo-arcilloso lómico).	[6] 120																	1	Do.
Santa Isabel loam (lómico)	[6] 120																	1	Do.
Serrano clay (arcilloso)	[3] 70							[2] 25			[2] 60					[4] 20	[4] 40	4	Sugarcane, grass (Caña de azúcar, yerba).
Serrano sandy clay loam (areno-arcilloso lómico).	[3] 70							[2] 40			[2] 60			[2] 50		[4] 15	[4] 40	4	Do.
Serrano (lómico)	[3] 60					[2] 50	[2] 15	[2] 40	[2] 40	[2] 40	[2] 60			[2] 60		[4] 10	[4] 40	5	Do.
Serrano sandy loam (arenoso lómico).	[6] 50					[2] 55	[2] 25	[2] 40	[2] 40	[2] 45	[2] 50			[2] 80		5	[4] 30	5	Do.
Soller clay (arcilloso)	75	[2] 60	[2] 50			75	[2] 100	25	[2] 90	[2] 90	35	[2] 15					70	3	Sugarcane (Caña de azúcar).
Soller clay loam (arcilloso lómico)			[2] 40			35	70	20	40	40							50	8	Subsistence crops, grass (Cultivos de subsistencia, yerba).
Soller clay loam, shallow phase (arcilloso lómico, fase poco-profunda).			[2] 40			40	30	15	35	35							10	9	Subsistence crops (Cultivos de subsistencia).
Soller clay loam, hilly phase (arcilloso lómico, fase en cerros).			[2] 40			25	25	10	35								40	8	Subsistence crops, grass (Cultivos de subsistencia, yerba).
Soller clay loam, steep phase (arcilloso lómico, fase escarpada).			[2] 40			25			30								35	9	Grass, subsistence crops (Yerba, cultivos de subsistencia).
Santa Clara clay (arcilloso)	75	[2] 60	60	[2] 40		85	[2] 95	30	80	80	65					[2] 50	75	3	Sugarcane, susbsistence crops (Caña de azúcar, cultivos de subsistencia).
Santa Clara clay loam (arcilloso lómico).	75	50				85	[2] 90	35	80	80	65					[2] 55	80	3	Do.
St. Lucie fine sand (arena fina)				[2] 10				15	10	10		10		25	20		15	10	Idle (Barbecho).
Tanamá stony clay (pedrego-arcilloso).			10			25		20	10	10	20		10				15	10	Trees, subsistence crops (Arboles, cultivos de subsistencia).
Tanamá stony clay, smooth phase (pedrego-arcilloso, fase lisa).		45				50	10	30	30	30	35	30					40	9	Trees, subsistence crops, onions (Arboles, cultivos de subsistencia, cebolla).

See footnotes at end of table.

TABLE 14.—*Productivity ratings of soils in Puerto Rico* (TABLA 14.—*Clasificación de los suelos de Puerto Rico a base de productividad*)—Con.

Soil type (Tipo de suelo)	Sugarcane (Caña de azúcar)	Tobacco (Tabaco)	Coffee (Café)	Grapefruit (Toronjas)	Pineapples (Piñas)	Bananas (Guineos)	Corn (Maíz)	Sweetpotatoes (Batatas)	Pigeonpeas (Gandules)	Beans (Habichuelas)	Yautia (Yautía)	Yucca (Yuca)	Yam or ñame (Ñame)	Coconuts (Cocos)	Cotton (Algodón)	Hay (Yerba de corte)	Pasture (Pasto)	General rating (Clasificación general)	Principal crops (Cultivos principales)
Tanamá stony clay, colluvial phase (pedrego-arcilloso, fase coluvial).		[2] 50	45	35		75	15	30	30	30	40	30	60				40	8	Subsistence crops, trees (Cultivos de subsistencia, árboles).
Talante silty clay loam (limo-arcilloso lómico).	80																	3	Sugarcane (Caña de azúcar).
Talante clay (arcilloso)	75																	3	Do.
Talante clay loam (arcilloso lómico).	75																	3	Do.
Talante loam (lómico)	70																	4	Do.
Talante sandy loam (arenoso lómico).	60	[2] 40																5	Do.
Talante fine gravel (grava fina)	75	[2] 45																3	Do.
Teresa clay (arcilloso)	[3] 115																[4] 30	2	Sugarcane, grass (Caña de azúcar, yerba).
Teresa silty clay loam (limo-arcilloso lómico).	[3] 115																[4] 30	2	Do.
Teresa loam (lómico)	[3] 120																[4] 30	2	Do.
Teja loam (lómico)	30	40				30	15	45	35	35	20	15		60			15	8	Subsistence crops (Cultivos de subsistencia).
Teja loam, steep phase (lómico, fase escarpada).		35				30	10	40	30	30	15	10					10	9	Grass, subsistence crops (Yerba, cultivos de subsistencia).
Teja loam, eroded phase (lómico, fase erosiva).	25	30				30	10	40	30	30	25	10					15	8	Subsistence crops (Cultivos de subsistencia).
Tiburones muck (muck)	[2] 40															[2] 60	60	10	Sedges (Juncos).
Toa silty clay (limo-arcilloso)	110	[2] 100																1	Sugarcane (Caña de azúcar).
Toa silty clay loam (limo-arcilloso lómico).	110	[2] 100																1	Do.
Toa silt loam (limoso lómico)	115	[2] 100																1	Do.
Toa silt loam, low-bottom phase (limoso lómico, fase fondo bajo).																100	150	8	Hay, grass (Yerba de corte, pasto).
Toa loam (lómico)	105	[2] 100																1	Sugarcane (Caña de azúcar).
Toa fine sandy loam (fino arenoso lómico).	45	[2] 95														100	150	6	Do.
Toa fine sandy loam, low-bottom phase (fino arenoso lómico, fase fondo bajo).																100	150	8	Hay, grass (Yerba de corte, pasto).

Torres clay (arcilloso)	60	60	80	----	[2] 85	90	50	35	50	50	60	30	85	----	----	50	60	5	Sugarcane, coffee (Caña de azúcar, café.)
Torres clay, steep phase (arcilloso, fase escarpada).	----	40	65	----	[2] 70	60	----	30	40	40	50	----	----	----	----	----	60	7	Coffee (Café).
Torres silty clay loam (limo-arcilloso lómico).	65	60	75	----	[2] 85	90	60	35	50	50	65	30	85	----	----	40	60	4	Sugarcane (Caña de azúcar).
Ursula clay (arcilloso)	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	[4] 25	10	Mangroves (Mangle).
Utuado loam (lómico)	----	50	70	----	----	55	25	40	40	60	30	15	----	----	----	20	25	6	Tobacco (Tabaco).
Utuado loam, smooth phase (lómico, fase lisa).	[2] 60	70	75	----	----	60	45	45	40	60	35	20	[2] 35	----	----	30	30	5	Do.
Vega Alta clay (arcilloso)	55	45	----	50	70	60	45	30	45	45	65	30	60	----	----	----	30	5	Sugarcane, subsistence crops (Caña de azúcar, cultivos de subsistencia).
Vega Alta clay, heavy-subsoil phase (arcilloso, fase subsuelo pesado).	50	45	----	----	70	40	45	35	45	45	65	30	60	----	----	----	30	5	Do.
Vega Alta sandy clay loam (areno-arcilloso lómico).	55	45	----	60	75	55	50	40	45	45	65	30	60	----	----	----	30	5	Do.
Vega Alta sandy clay loam, heavy-subsoil phase (areno-arcilloso lómico, fase subsuelo pesado).	50	40	----	----	70	50	45	40	45	45	65	30	60	----	----	----	30	5	Do.
Vega Alta clay loam (arcilloso lómico).	60	45	----	----	75	60	50	45	55	55	45	30	45	----	----	----	30	5	Do.
Vega Alta clay loam, heavy-subsoil phase (arcilloso lómico, fase subsuelo pesado).	55	40	----	----	70	50	45	60	45	45	60	30	55	----	----	----	30	5	Sugarcane (Caña de azúcar).
Vega Alta clay loam, poorly drained phase (arcilloso lómico, fase drenaje pobre).	65	----	----	----	----	----	----	----	----	----	----	----	----	----	----	65	50	5	Do.
Vega Alta fine sandy loam (fino arenoso lómico).	30	30	----	60	----	45	15	95	40	40	----	20	----	----	[2] 60	----	50	6	Grapefruit, subsistence crops (Toronjas, cultivos de subsistencia).
Vega Alta loamy fine sand (arena fina lómica).	20	20	----	85	----	45	10	95	40	40	----	20	----	----	[2] 60	----	50	6	Do.
Vega Baja clay (arcilloso)	90	----	----	----	----	----	----	----	----	----	100	----	----	----	----	100	150	2	Sugarcane (Caña de azúcar).
Vega Baja silty clay (limo-arcilloso).	75	----	----	----	----	----	----	----	----	----	90	----	----	----	----	90	100	3	Do.
Vía silty clay (limo-arcilloso)	70	75	85	[2] 70	----	100	[2] 70	50	40	40	65	[2] 65	----	----	----	80	80	3	Do.
Vía silty clay, broken phase (limo-arcilloso, fase quebrada).	50	50	70	----	----	65	----	40	----	----	----	----	----	----	----	----	65	8	Grass (Yerba).
Vía clay loam (arcilloso lómico)	65	75	85	70	----	100	[2] 70	55	40	40	65	[2] 65	----	----	----	80	80	4	Sugarcane (Caña de azúcar).
Vía silt loam (limoso lómico)	70	80	90	[2] 65	----	100	[2] 70	60	40	40	65	[2] 65	80	----	----	80	----	3	Do.
Vía silt loam, broken phase (limoso lómico, fase quebrada).	50	50	75	----	----	65	----	55	----	----	----	----	----	----	----	----	80	8	Grass (Yerba).

See footnotes at end of table.

TABLE 14.—*Productivity ratings of soils in Puerto Rico* (TABLA 14.—*Clasificación de los suelos de Puerto Rico a base de productividad*)—Con.

Soil type (Tipo de suelo)	Sugarcane (Caña de azúcar)	Tobacco (Tabaco)	Coffee (Café)	Grapefruit (Toronjas)	Pineapples (Piñas)	Bananas (Guineos)	Corn (Maíz)	Sweetpotatoes (Batatas)	Pigeonpeas (Gandules)	Beans (Habichuelas)	Yautia (Yautía)	Yucca (Yuca)	Yam or ñame (Ñame)	Coconuts (Cocos)	Cotton (Algodón)	Hay (Yerba de corte)	Pasture (Pasto)	General rating (Clasificación general)	Principal crops (Cultives principales)
Vieques loam (lómico)	[7] 20	[2] 40					15	20	20	20							25	8	Grass (Yerba).
Vieques loam, steep phase (lómico, fase escarpada).																	15	10	Do.
Vieques loam, undulating phase (lómico, fase ondulante).	[7] 25	[2] 45				[2] 40	[2] 25	[2] 25	[2] 20	[2] 20		[2] 15					30	6	Sugarcane (Caña de azúcar).
Vieques loam, colluvial phase (lómico, fase coluvial).	[7] 25	[2] 45				55	[2] 25	25	20	25		15					30	6	Do.
Viví silty clay loam (limo-arcilloso lómico).	95	[2] 100	80			[2] 90	[2] 60											3	Do.
Viví clay (arcilloso)	95		80			90	[2] 60											3	Do.
Viví clay loam (arcilloso lómico)	95		80			90	[2] 60											3	Do.
Viví clay loam, shallow phase (arcilloso lómico, fase poco-profunda).	50		80													60	60	6	Grass, sugarcane (Yerba, caña de azúcar).
Viví loam (lómico)	75	100	[2] 100			85	[2] 60	[2] 80	[2] 60	[2] 55								4	Sugarcane (Caña de azúcar).
Viví loam, shallow phase (lómico, fase poco-profunda).	45															60	60	6	Sugarcane, grass (Caña de azúcar, yerba).
Viví silt loam (limoso lómico)	[2] 85	100	85			80	[2] 70											3	Sugarcane (Caña de azúcar).
Viví sandy loam (arenoso lómico)	60	[2] 80	[2] 80			65	[2] 50	[2] 80	[2] 55	[2] 45								5	Do.
Viví loamy sand (arena lómica)	[2] 35	[2] 60	[2] 75			60		[2] 85	[2] 40	[2] 40							70	4	Subsistence crops (Cultivos de subsistencia).
Vives clay loam (arcilloso lómico)	[6] 95																	1	Sugarcane (Caña de azúcar).
Vives clay loam, steep phase (arcilloso lómico, fase escarpada).																	60	9	Grass (Yerba).
Vives clay loam, colluvial phase (arcilloso lómico, fase coluvial).	55																	5	Sugarcane (Caña de azúcar).
Vives sandy loam (arenoso lómico)	45																	5	Do.
Vives loam (lómico)	[6] 95																	1	Do.
Vayas clay (arcilloso)	[6] 110																	1	Do.
Vayas silty clay loam (limo-arcilloso lómico).	[6] 115																	1	Do.
Vayas silt loam (limoso lómico)	[5] 120																	1	Do.
Vayas loam (lómico)	[6] 115																	1	Do.
Yabucoa clay (arcilloso)	55															90	95	4	Do

Yabucoa clay loam (arcilloso lómico).	75	---	---	---	---	---	---	---	---	---	[2]100	---	---	---	---	95	95	3	Do.
Yabucoa loam (lómico)	75	---	---	---	---	---	---	---	---	---	[2]95	---	---	---	---	90	90	3	Do.
Yauco clay (arcilloso)	[6]95	50	---	---	---	45	70	[2]30	60	70	---	---	---	---	45	---	40	2	Do.
Yauco clay, colluvial phase (arcilloso, fase coluvial).	[6]80	55	---	---	---	50	75	[2]30	60	60	---	---	---	---	45	---	45	3	Do.
Yunes clay (arcilloso)	---	---	[2]45	---	---	60	---	25	---	---	35	---	---	---	---	---	25	8	Trees, subsistence crops (Arboles, cultivos de subsistencia).
Yunes silt loam (limoso lómico)		---	---	---	---	55	---	20	---	---	---	---	---	---	---	---	30	9	Grass (Yerba).

[1] This crop was not observed growing on this soil in large enough acreage to definitely assign a rating; therefore, the rating is only an estimate.

(Esta cosecha no se observó cultivándose en suficiente extensión para asignarle definidamente una clasificación; por lo tanto, la clasificatión es estimada.)

[2] This crop is seldom grown on this soil, but when grown it would have about this rating.

(Esta cosecha rara vez se cultiva en este suelo, pero si se cultivara llegaría a esta clasificación.)

[3] This crop is irrigated and grown on nonsalty or nonalkali areas of this soil.

(Esta cosecha se riega y cultiva en áreas de este suelo que no son salinas y alcalinas.)

[4] This crop is grown on salty or alkali areas of this soil.

(Esta cosecha se cultiva en áreas salinas y alcalinas de este suelo.)

[5] This rating refers to the production of this crop on areas not exceeding 600 feet in elevation.

(Este clasificación se refiere a la productividad de esta cosecha en áreas no mayor de 600 pies de altitud.)

[6] This rating is for the production of this crop on irrigated areas of this soil. Nearly 100 percent of the soil is irrigated.

(Esta clasificación es para la producción de esta cosecha en áreas de este suelo, bajo riego. Cerca del 100 por ciento de este suelo está bajo riego.)

[7] This crop is seldom fertilized when planted on this soil.

(Esta cosecha es rara vez abonada cuando se siembra en este suelo.)

[8] The rating of this crop on this soil is for areas receiving some irrigation water. Without irrigation the rating would be about 20 percent less.

(La clasificación de esta cosecha en este suelo es para áreas que reciben algún riego. Sin riego, la clasificación sería 20 por ciento menor.)

[9] This rating refers to areas of this soil that have been adequately drained for the production of this crop.

(Esta clasificación se refiere a áreas de este suelo que han sido drenadas debidamente para la producción de esta cosecha.)

The ratings compare the productivity of each of the soil types or other mapping units on the island for a given crop to a standard, namely, 100. This standard represents the average acre yield obtained from the most productive soil type or types producing the given crop under current practices. A soil with an index of 50 produces an acre yield of about one-half of that produced by the soil having the standard index. In some instances, owing to irrigation or very favorable conditions for the growth of certain crops, some soils have an index exceeding 100.

The current farming practices on the well-managed farms include amendments, such as lime, ammonium sulfate, complete commercial fertilizers, or a combination of these amendments, for certain crops, such as sugarcane, tobacco, grapefruit, ñames, and pineapples. The quantity of fertilizer applied ranges from 600 to 1,200 pounds to the acre. In some fields, such crops as corn, beans, pigeonpeas, and yautias obtain some of the unused and unleached fertilizer applied for the preceding tobacco crop. In most fields, these subsistence crops, as well as bananas, yuca, and sweetpotatoes, are seldom fertilized, because generally they are grown in gardenlike patches by the jibaros, who do not have sufficient means for purchasing fertilizers. Hay land and pastures are never fertilized, and coconuts rarely. Cotton receives some fertilizer, and the most productive coffee farms receive either fertilizer or manure, or both.

The factors influencing the productivity of well-managed land are mainly those of climate, soil, and relief; and all are concerned in the determination of the productivity ratings. Low ratings for a particular crop on a certain soil type may as likely be due to unfavorable relief, too little or too much moisture, too high or too low elevation, or nearness to the seashore, as to a lack of fertility in the soil or unfavorable soil characteristics. Crop yields from well-managed farms furnish the best available summation of the factors contributing to soil productivity, and therefore they have been made the bases, so far as such information is available, for the determination of the indexes. Some soils, such as the Toa, Coloso, San Antón, and Altura, are used almost entirely for the production of sugarcane. These soils are the most productive for many crops, but they are rated only for sugarcane. Most of them undoubtedly would have a rating far exceeding 100 for many truck crops, such as yautias, beans, pigeonpeas, and bananas, but as these crops cannot compete with cane on this valuable productive land they are not grown, and therefore any rating given crops other than sugarcane on this land would be estimated. As a general rule the soils are used for the crop or crops for which they are best adapted. The soils that have a rating for only one or two crops either are exceedingly well adapted to those specific crops and generally have a high rating, or they are poorly adapted to any of the commercial crops and are used only for pasture, hay, or subsistence crops and therefore have a low rating.

The soils of a given series may occupy an area having sufficient range in elevation to affect the yield of certain crops or even the kind of crops produced. These particular soils and crops are indicated in the table by footnotes. The soils of nearly all series occupy areas having some range in average annual precipitation. As mapped, those of some series have a much wider range of precipitation than those of others. As a general rule, the range is not so great as to affect materially either the kind of crop or the average acre yield for a particular soil type within the series. Some soil types of a certain soil series, however, may occur within an area having enough difference in climatic conditions to cause it to have a different rating from other soil types of the same series. For example, Yunes silt loam occurs where the rainfall is not sufficient for the production of coffee and therefore does not have a rating for coffee, but Yunes clay occurs in areas receiving sufficient rainfall for the production of coffee, although the difference in rainfall is not sufficiently great materially to affect the soil profiles of the two types, other than in the texture of the surface soil. A phase of a soil type generally has characteristics that materially affect its productivity rating, and it may rate less than one-half that of the typical soil.

Footnotes in table 14 indicate the soils that are irrigated, seriously affected with salt, drained, and not fertilized for crops commonly fertilized. Crops seldom grown on certain soil types are indicated also, as well as the principal crops grown on each soil separation. The table also shows a general rating of the soils in addition to the productivity rating of each soil separation for the various crops. The general ratings are based on soil profile, relief, susceptibility to destructive erosion, amount of water received, either by irrigation or from precipitation, the amount of drainage necessary for crop production, and to a certain extent the management of the soil as well as the productivity of the land. The level permeable deep soils have higher ratings than shallow soils or those on steep slopes. Soils such as the Colinas, although fairly productive now, are rated slightly lower than soils less susceptible to erosion. Soil types occurring in arid sections are rated lower than similar soils in humid sections, unless the soil in the arid district is now under irrigation. Soils that are difficult to drain or cultivate are rated lower than well-drained soils or those that are easily managed.

The most productive land has a rating of 1, and the least productive rates 10. It must be clearly understood that the productivity ratings are not to be interpreted directly into specific land values. The intention is to confine attention to essentially permanent factors of productivity and not to include transitory economic considerations. In some instances the information on which the ratings are based is not so complete as desired; in such instances further study may suggest changes.

The following tabulation gives some of the numerical acre yields that have been set up as standards of 100 when applied to the soil type of significant acreage that produces the highest yield of a specific crop.

They represent long-time production averages under the current farming practice for each of the most important crops grown on the island.

Crop:		
Sugarcane (gran cultura)	tons	60
Tobacco	pounds	1,800
Coffee	do	[1] 600
Grapefruit	boxes	[1] 600
Pineapples	crates	500
Bananas	fingers	60,000
Corn	pounds	2,000
Sweetpotatoes	do	6,000
Pigeonpeas	do	500
Beans	do	500
Yautias	do	5,000
Yuca	do	2,500
Ñames	do	8,000
Coconuts	nuts	6,000
Cotton	pounds	[2] 1,000
Hay, mostly malojillo grass	tons	20
Pasture	cow-acre-days [3] per year	700

[1] These figures may appear high for the present production. They are based, however, on a long-time average annual production for well-managed healthy trees in prime condition.
[2] Seed cotton; 100 pounds of seed cotton is equal to about 27 pounds of lint.
[3] Cow-acre-days is a term used to express the carrying capacity of pasture land. As used here it is the product of the number of animal units carried per acre multiplied by the number of days the animals are grazed without injury to the pasture. For example, the soil type able to support 1 animal unit per acre for 360 days of the year rates 360, whereas another soil able to support 1 animal unit per 2 acres for 180 days of the year rates 90. Again, if 4 acres of pasture support 1 animal unit for 100 days the rating is 25.

Table 15 gives the approximate yield for each crop for each rating. This is for convenience in reading table 14.

TABLE 15.—*Approximate yield for each crop for each rating*

Rating	Sugarcane	Tobacco	Coffee	Grapefruit	Pineapples	Bananas	Corn	Sweetpotatoes	Pigeonpeas	Beans	Yautia	Yuca	Ñame or yam	Coconuts	Cotton	Hay	Pasture
	Tons	*Pounds*	*Pounds*	*Boxes*	*Crates*	*Fingers*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Number*	*Pounds*	*Tons*	*Cow-acre-days*
5	3	90	30	30	25	3,000	100	300	25	25	250	125	400	300	50	1	35
10	6	180	60	60	50	6,000	200	600	50	50	500	250	800	600	100	2	70
15	9	270	90	90	75	9,000	300	900	75	75	750	375	1,200	900	150	3	105
20	12	360	120	120	100	12,000	400	1,200	100	100	1,000	500	1,600	1,200	200	4	140
25	15	450	150	150	125	15,000	500	1,500	125	125	1,250	625	2,000	1,500	250	5	175
30	18	540	180	180	150	18,000	600	1,800	150	150	1,500	750	2,400	1,800	300	6	210
35	21	630	210	210	175	21,000	700	2,100	175	175	1,750	875	2,800	2,100	350	7	245
40	24	720	240	240	200	24,000	800	2,400	200	200	2,000	1,000	3,200	2,400	400	8	280
45	27	810	270	270	225	27,000	900	2,700	225	225	2,250	1,125	3,600	2,700	450	9	315
50	30	900	300	300	250	30,000	1,000	3,000	250	250	2,500	1,250	4,000	3,000	500	10	350
55	33	990	330	330	275	33,000	1,100	3,300	275	275	2,750	1,375	4,400	3,300	550	11	385
60	36	1,080	360	360	300	36,000	1,200	3,600	300	300	3,000	1,500	4,800	3,600	600	12	420
65	39	1,170	390	390	325	39,000	1,300	3,900	325	325	3,250	1,625	5,200	3,900	650	13	455
70	42	1,260	420	420	350	42,000	1,400	4,200	350	350	3,500	1,750	5,600	4,200	700	14	490
75	45	1,350	450	450	375	45,000	1,500	4,500	375	375	3,750	1,875	6,000	4,500	750	15	525
80	48	1,440	480	480	400	48,000	1,600	4,800	400	400	4,000	2,000	6,400	4,800	800	16	560
85	51	1,530	510	510	425	51,000	1,700	5,100	425	425	4,250	2,125	6,800	5,100	850	17	595
90	54	1,620	540	540	450	54,000	1,800	5,400	450	450	4,500	2,250	7,200	5,400	900	18	630
95	57	1,710	570	570	475	57,000	1,900	5,700	475	475	4,750	2,375	7,600	5,700	950	19	665
100	60	1,800	600	600	500	60,000	2,000	6,000	500	500	5,000	2,500	8,000	6,000	1,000	20	700
105	63	—	—	—	—	—	—	—	—	—	—	—	8,400	—	—	—	—
110	66	—	—	—	—	—	—	—	—	—	—	—	8,800	—	—	—	—
115	69	—	—	—	—	—	—	—	—	—	—	—	9,200	—	—	—	—
120	72	—	—	—	—	—	—	—	—	—	—	—	9,600	—	—	—	—
125	75	—	—	—	—	—	—	—	—	—	—	—	10,000	—	—	—	—
130	78	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
135	81	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
140	84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
145	87	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
150	90	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
155	93	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
160	96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

CLASIFICACIÓN A BASE DE PRODUCTIVIDAD

La tabla número 14 da una clasificación de cada tipo y fase de suelo, a base de la productividad de los cultivos generalmente cosechados en los mismos. La clasificación compara la productividad de cada uno de los tipos de suelos de la isla dando un valor de 100 al rendimiento por acre promedio obtenido en el tipo o tipos de suelos más productivos de P. R. siguiendo las prácticas de cultivo corrientes. Un suelo con un índice de 50 produce un rendimiento por acre de más o menos la mitad del producido por aquel suelo que tiene el índice de 100. En algunos casos, debido a riego o condiciones muy favorables para el crecimiento de ciertos cultivos, algunos suelos tienen un índice de más de 100.

Las prácticas agrícolas corrientes en las fincas bien administradas comprenden aplicaciones de cal, sulfato de amonio, abonos completos, o una combinación de estas enmiendas, para ciertos cultivos, como caña de azúcar, tabaco, toronjas, ñames y piñas. La cantidad de abono aplicada varía de 600 a 1,200 libras por acre. En algunos sitios cultivos como maíz, habichuelas, gandules y yautía, utilizan parte del abono que no ha sido lavado o utilizado por la cosecha de tabaco sembrada anteriormente. En la mayor parte de los casos, estos cultivos de subsistencia, tales como guineos, yuca y batatas, no se abonan, porque generalmente son sembrados en pequeños huertos por campesinos que no pueden comprar abono.

Los pastos nunca se abonan y los cocos rara vez. El algodón se abona algo y las fincas de café más productivas o se abonan o se les aplica estiércol o ambas cosas.

Los factores que ejercen influencia sobre la productividad de tierra bien administrada son principalmente: clima, suelo y topografía; todos ellos son tomados en consideración para la determinación de los índices de productividad. Indices bajos para un cultivo dado en cierto tipo de suelo pueden ser debidos lo mismo a topografía desfavorable, que a mucha o poca humedad, a una elevación alta o baja, a cercanía de la costa, a falta de fertilidad en el suelo, o a características desfavorables del mismo. Rendimientos de cosechas en las fincas bien administradas agrupan todos los factores que contribuyen a la productividad del suelo, y por lo tanto, sirven de base, siempre que tal información haya sido asequible, para la determinación de los índices de productividad. Algunos suelos, tales como los de las series Toa, Coloso, San Antón y Altura, se siembran casi totalmente de caña de azúcar.

Estos suelos son los más productivos de la isla para muchos cultivos, pero solamente han sido clasificados para caña de azúcar. Muchos de estos suelos indudablemente tendrían un índice de mucho más de 100 para hortalizas o frutos menores, tales como yautías, habichuelas, gandules, etc., pero como estos cultivos no pueden competir con la caña de azúcar en estos suelos, no se siembra ninguno de ellos en los mismos y por lo tanto cualquier índice dado a ellos sobre esos cultivos sería un cálculo aproximado. Como regla general los suelos se siembran de los cultivos que se adapten mejor. Los suelos que tienen un índice solamente para uno o dos cultivos que se adaptan bien tienen un índice alto. Los que se adaptan pobremente para los cultivos comerciales y se usan solamente para pastos y cultivos de subsistencia tienen un índice bajo.

Los suelos de una serie dada pueden ocupar un área que tenga suficiente variación en elevación para afectar el rendimiento de ciertos cultivos. Dichos suelos y cultivos están indicados en la tabla por anotaciones al calce. Los suelos de casi todas las series ocupan áreas que tienen cierta variación en precipitación pluvial anual promedio. Según están localizados en el mapa, los suelos de algunas series tienen una variación mayor en precipitación que aquellos de otras. Como regla general la variación no es lo suficientemente grande para afectar notablemente la clase de cultivo o el rendimiento promedio por acre para un tipo dado dentro de la serie. Sin embargo, algunos tipos de suelo de cierta serie pueden ocurrir dentro de un área cuyas condiciones climatológicas sean lo suficientemente distintas para tener que darle un índice distinto a los otros tipos de la serie, por ejemplo el suelo Yunes limoso-lómico ocurre donde la lluvia no es suficiente para producir café y por lo tanto no tiene índice para café, pero Yunes arcilloso ocurre en áreas con suficiente lluvia para la producción de café, aunque la diferencia en precipitación no es lo suficientemente grande para causar diferencias en el perfil de los dos tipos excepto en la textura del suelo de la superficie. Una fase de un tipo de suelo, generalmente tiene características que afectan materialmente el índice de productividad; este puede ser menos de la mitad del índice del suelo típico.

Anotaciones al final de la tabla 14 indican los suelos que tienen riego, que están afectados por sales y avenados y no son abonados y aquellos cultivos rara vez sembrados en ciertos tipos de suelo, así como los cultivos principales en cada tipo. La tabla 14 muestra también un índice de productividad general de los suelos además del índice individual de cada suelo para los distintos cultivos. El índice general está basado en el perfil del suelo, topografía, susceptibilidad a erosión destructiva, cantidad de agua recibida por riego o por lluvia, la cantidad de avenamiento necesario para producir cosechos y hasta cierto punto la administración del suelo y la productividad de la tierra. Los suelos llanos, permeables y profundos tienen más alta clasificación que los suelos poco profundos o aquellos de declive escarpado. Suelos tales como el Colinas, aunque medianamente productivos, están clasificados un poco más bajos que suelos menos susceptibles a erosión. Tipos de suelo de zonas áridas tienen un índice más bajo que suelos similares en zonas húmedas, a menos que el suelo en la zona árida esté bajo riego actualmente. Suelos difíciles de avenar o de cultivar tienen un índice más bajo que suelos bien avenados o fáciles de trabajar.

El suelo más productivo tiene un índice de 1, y el menos productivo de 10.

Los índices de productividad no deben ser interpretados directamente como valor específico de la tierra. La intención es darle atención a factores esenciales permanentes de productividad y no incluir consideraciones económicas transitorias. En algunos casos la información sobre la cual se basa la clasificación no fué tan completa como se deseaba; en estos casos un estudio más completo sugeriría cambios.

A continuación anotamos algunos de los rendimientos máximos por acre de cosechas tropicales que se toman como base de 100 para clasificar los suelos a base de su productividad. Estos promedios represen-

tan producción por muchos años, usando las prácticas agrícolas corrientes.

Algodón	libras	[1] 1,000
Batatas	íd	6,000
Café	íd	[2] 600
Caña de azúcar (gran cultura)	toneladas	60
Cocos	cocos	6,000
Gandules	libras	500
Guineos	guineos	60,000
Habichuelas	libras	500
Maíz	íd	2,000
Ñames	íd	8,000
Pastos	días-acre por vaca [3] por año	700
Piñas	jaulas	500
Tabaco	libras	1,800
Toronjas	cajas	[2] 600
Yautías	libras	5,000
Yerba de corte, principalmente malojillo	toneladas	20
Yuca	libras	2,500

[1] Algodón en rama, 100 libras de algodón en rama es igual a más o menos 27 libras de fibra.
[2] Estos índices pueden parecer altos para la producción actual de la isla. Sin embargo están basados en datos de producción de muchos años de árboles sanos, en las mejores condiciones.
[3] Días-acre por vaca se usa para expresar la capacidad de los pastos. Es el equivalente del número de cabezas de ganado mantenidas por un acre durante un número de días determinado sin que el pasto sufra deterioro.

La tabla 15 dá el rendimiento aproximado para cada cultivo por índice de productividad. Esto hace más fácil la lectura de la tabla 14.

ALKALI AND SALINE SOILS

The common use of the word "alkali" in reference to soils denotes any soluble salt occurring in sufficient quantity to be toxic to plants. The occurrence of the salt in the soil may be traced to any one or more of several sources. Along the level narrow coastal strips affected by tides and in the poorly drained soils that are only slightly above sea level, the ocean water generally is the source. In the process of soil formation, especially during the distintegration and decomposition of rock, various salts are liberated and therefore are the source in most of the soils inland from the coast. In the humid sections most of the harmful salts, as well as many of the beneficial ones, are soon leached by the percolating soil moisture, but in Puerto Rico, in areas receiving less than 45 inches of annual rainfall, the precipitation is not sufficient to leach the salts to a great depth. When the land is irrigated without adequate drainage, there is danger of a rise in the water table, which will bring sufficient quantities of the salts to the surface to cause injury to plants. In some places the percolating water dissolves the salt liberated by decomposition and carries it to the ground water; but if this salty water is pumped to the surface and used for irrigation the salt will accumulate in the soil and may become harmful to plants.

Another source of salt is in the so-called tumors that are numerous in certain areas along the south coast. The ground water on its way from the mountainous interior to the sea seems to have unusually strong pressure beneath the low level soils of the alluvial fans. In places the pressure is so great that water and colloidal materials are forced to the surface, forming mounds, or tumors, ranging from 3 to 4 feet in height, 10 to 15 feet in length, and 8 to 10 feet in width. In most places, water and soil material from the tumors are strongly charged with salts high in sodium carbonate, which kill the vegetation in places where they spread over the land. In other parts of the

south coast on the level alluvial fans, ground water will rise to a level within a foot or two of the surface when holes are dug through the compact subsoil. This indicates that, owing to the great pressure, if the ground water contains salt it will be forced up into the surface soil. Some fairly deep lying soil layers contain considerable salt, and this salt is brought to the surface soil by the rising water table or by the movement of water after irrigation has been practiced for a few years.

The most common salts include the chlorides, sulfates, carbonates, and nitrates of sodium and potassium, the chlorides and nitrates of calcium and magnesium, and magnesium sulfate.

In Puerto Rico the alkali and saline lands are confined to the level or slightly undulating areas in the arid and semiarid districts and the level narrow coastal strips in both the arid and humid districts affected by tides or influenced by salty ground water. In the arid districts, inland from the mangrove swamps, most of the salts are sodium carbonate (true alkali) and sodium bicarbonate. The former is called black alkali, owing to the black or brown stain or incrustation caused by the solvent action of the alkali on the organic matter. The mangrove swamps and other salty areas near the sea contain mostly sodium chloride, calcium chloride, sodium sulfate, and magnesium sulfate. When these salts occur in high concentration and are dried they produce a white incrustation on the surface of the soil. They give rise to the so-called white alkali soils, but chemically these are saline soils. In areas where the black-alkali areas join the white-alkali areas, there is a mixture of the two kinds of salts.

Most areas affected with harmful quantities of salt can be identified by the general appearance of the land or by the vegetation. Areas that have over 2 or 3 percent of salt, of either the black or the white variety, are nearly barren or support vegetation (fig. 128) only on small hummocks or on elevations higher than the area as a whole. The high concentration of salt makes the soil particles fluffy and easily blown by the wind after being trampled by livestock. In most areas seriously affected by black alkali there are many barren spots, several yards in diameter, from which the topmost 8 or 10 inches of the surface soil has disappeared, and the grass-covered areas stand out like flat, square toadstools. The salt solution deflocculates the soil and organic matter, and they are easily carried away by rains or wind. The soil also loses its structure and becomes sticky and plastic, and it then puddles readily.

Areas most likely to be affected by alkali are depressions and lower-lying ones having a high water table. In many areas the soil has a heavy or nearly impervious subsoil, and the rain or irrigation water penetrates to the subsoil, then moves laterally toward lower elevations, carrying with it the salt that dissolves along the way. The water eventually comes to the surface or near the surface in low areas or depressions, where evaporation causes a concentration of salt sufficient to kill most vegetation.

The salt content of the soil can be estimated in many places by observing the kinds of plants produced and the condition of the crops. As has been stated, nearly all soils having more than 3 percent of salt on the air-dry basis are barren of vegetation, except in swamps where the movement of water is such that the concentration of the salt solution is not so great as in the air-dry soil. Under

those conditions mangroves thrive very well on soil with more than 3 percent of salt. The barilla is a halophytic plant (fig. 129) that generally grows where the content of white alkali ranges between 1 and 3 percent. The verdolaga rosada generally is closely associated with the barilla and will grow in areas containing nearly 3 percent of salt. It may also grow in areas having less than 1 percent if the salt is sodium carbonate. Junquillo, a sedge, is nearly always an indicator of black alkali, and the concentration may range from 0.2 to 3 percent. In the areas having a high concentration, there are many

FIGURE 128.—Typical sequence of plants on saline soils. Cacti, barilla, no vegetation, and mangroves, one after the other, with increase in the salt content.

Secuencia típica de plantas en suelo salino. Cacti, barilla, áreas sin vegetación y mangles, uno detrás del otro, según aumenta el contenido de sal.

barren spots, and the land is wet for many months during the year.

Evolvulus glaber and *Jacquemontia subsalina* are salt-loving plants that commonly grow on white-alkali areas having from 1 to 2 percent of salt, but they will also grow on the black-alkali land having the same salt content. Bermuda grass, horquetillo, and grama de la playa will grow in areas having as high as 0.6 percent of alkali, if most of it is white alkali. These plants will also grow on salt-free land.

A luxuriant growth of cattail is generally an indication that the salt content is less than 0.4 percent. Australian pine, date palm, maya, and many other plants are tolerant of rather high concentrations of salt. Sugarcane will not grow on areas having more than 0.2 percent of either the black or the white alkali in the topmost foot of soil. If the material in this layer contains less than 0.2 percent and the next 1-foot layer has a fairly high concentration of either

black or white alkali, sugarcane will grow to a limited extent, but it will produce a low tonnage. Cane affected with alkali will become yellow, stop growing, and finally die. The cane will not germinate in spots having more than 0.4 percent of salt in the surface soil.

It is not uncommon to see excellent sugarcane growing within 2 feet of soil so highly impregnated with salt that the cane would not germinate (fig. 130). This is especially true with black-alkali spots. The change from the good cane to no germination is more gradual on white-alkali areas.

The character and quantity of salts in the soil are of extreme importance in determining the feasibility of irrigation and the best use for the land. Most lands that are to be irrigated in the arid sections

FIGURE 129.—A study of halophytic vegetation near the south coast of Puerto Rico. Mangroves in left background. Colony of barilla in foreground. Verdolaga rosada (*Sesuvium portulacastrum*) just to left of figure. Matojo de playa between figure and right background. White patches are crystallized soluble salt (*35*).

Estudio de la vegetación halófila cerca de la costa sur de Puerto Rico. Mangles al fondo a la izquierda. Colonia de barilla al frente. Verdologa rosada (*Sesuvium portulacastrum*), a la izquierda de la figura. Matojo de playa entre la figura y al fondo derecha. Manchas blancas son sal soluble cristalizada (*35*).

should first be tested, in order to discover whether harmful quantities of salt occurring in the soil layers are likely to be carried to lower elevations by percolating waters, or whether they may come directly to the surface during dry periods. Many hillsides having a loose friable or gravelly subsoil are subject to seepage if the land is irrigated or even if the canals along the hillsides are unlined. The seepage water may carry considerable salt, and when deposited on the surface of the soil, alkali areas are formed.

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The alkali areas along most of the southern coast are fairly easy to determine, because almost all of the level land not in swamps has been planted to cane at one time or another, and areas that contain too much alkali for the production of sugarcane produce only halophytic plants or grass. These areas can be accurately shown on a soil map, especially with the aid of aerial photographs.

The percentage of salt in any given area is exceedingly variable, as the salt content may be from two to eight times as high in one spot as it is in a spot just a few feet away, although both spots have the same general appearance. Again, the concentration will vary from

FIGURE 130.—Vertical aerial photograph of approximately 200 acres of the San Antón, Fé, Guánica, and associated soils near Central Guamaní along the south coast. This area is seriously affected with both alkali and salt, as indicated by the symbols. Excellent cane is produced within a few feet of areas so thoroughly impregnated with salt and alkali that the cane will not germinate: *A*, 0.2 to 0.5 percent of salt; *M*, 0.5 to 0.9 percent of salt; *Mc*, 0.5 to 0.9 percent of alkali; and *Sc*, 1 to 3 percent of alkali.

Vista aérea vertical de aproximadamente 200 acres de los suelos San Antón, Fé, Guánica y asociados cerca de la Central Guamaní en la costa sur. Esta área está seriamente afectada con álcali y sal como indican los símbolos. Caña excelente es producida a unos pies de las áreas impregnadas con sal y álcali donde la caña no germina. *A*, 0.2 a 0.5 por ciento de sal; *M*, 0.5 a 0.9 por ciento de sal; *Mc*, 0.5 a 0.9 por ciento de álcali; y *Sc*, 1 a 3 por ciento de álcali.

year to year or season to season, depending on the amount of moisture in the ground and the height of the water table.

Quantitative determinations of the approximate salt content of the soils were made by use of the electrolytic bridge (fig. 131). Samples for salt determination were collected by 1-foot sections in carefully

selected locations, some of which represented spots of maximum concentration, whereas others represented the lower or gradational degrees of accumulation. Notes were taken as to the amount and kind of vegetation in places where the sample was taken. The content of

FIGURE 131.—Determining the salt content of soils with the electrolytic bridge. Determinando el contenido de sal de los suelos salinos.

salt was determined in the laboratory, and the results were tabulated and indicated in red ink in the correct location on the soil-survey map. The salt concentration of each sample is shown on the accompanying map in the form of a fraction, as $\frac{.20}{.40}$. The upper number indicates the content of salt in the topmost 1 foot of soil, and the lower indicates the average salt content to a depth of 4 or 5 feet.

Three different grades of salt accumulation are shown on the map, and within each grade the black and the white alkali are shown separately. The letter C is placed in the areas that are impregnated with the carbonates, or black alkali. The first grade, or areas only slightly affected with alkali, have a concentration of 0.2 to 0.5 percent, so distributed throughout the soil profile as to be a limiting factor in crop production. Most of such areas, however, can be reclaimed by a good drainage system and careful management. Areas affected with black alkali are exceedingly difficult to reclaim, but by adding sulfur and large quantities of manure, in addition to adequate drainage, fair results are obtained. Areas in which considerable salt is in the subsoil should not be plowed deep, in order that the salts may not be brought nearer to the surface. The vegetation on soils having from 0.2 to 0.5 percent of salt consists chiefly of Bermuda grass, grama de la playa, and horquetilla. A few bare areas occur, and in some places the production of sugarcane has been attempted, but the cane has died.

FIGURE 132.—Microrelief on soils affected with sodium bicarbonate. One-step-high grassed islandlike areas surrounded by bare soil.

Microrelieve en suelos afectados por bicarbonato de sodio. Areas cubiertas de yerba alta rodeadas por suelo limpio.

The second grade, or areas moderately affected with alkali, has a concentration ranging from 0.5 to 0.9 percent salt, so distributed throughout the soil profile as to affect adversely even some of the salt-resistant grasses. Most of these areas support some salt-loving vegetation, such as alkali grass or junquillo. It would be exceedingly difficult and probably very expensive to reclaim such land.

The third grade, or strongly affected areas, has a concentration exceeding 1 percent. Such areas include many barren spots, and many areas have a thin white crust underlain by a white fluffy powder when dry. The soil in this grade is very salty from the surface to a great depth. It includes most of the mangrove swamps and swamplands, which are only 4 or 5 inches above sea level. On the better drained areas barilla and verdolaga rosada are the main vegetation. Figure 132 shows an area affected by sodium bicarbonate.

Areas designated on the map by a C have a high concentration of carbonates and are easily identified by the sedge, junquillo. Such areas generally are wet after a rain, and water may stand on the sur-

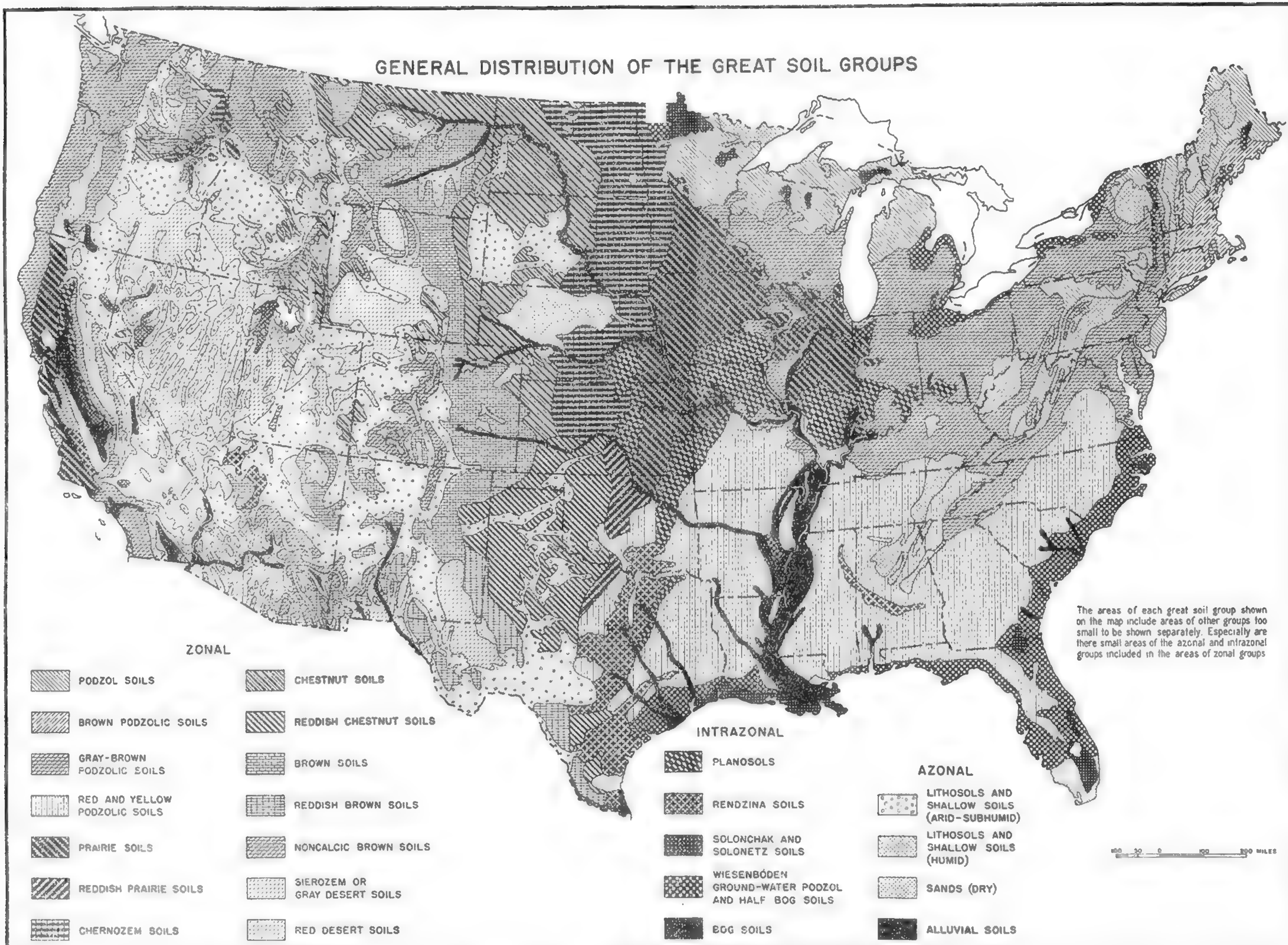

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FIGURE 133.—General distribution of the important groups of soils in the United States.

face for some time, owing to the compact layers produced by the sodium carbonate. This salt causes the soil particles to be deflocculated and run together to such an extent that it is very difficult for water to penetrate to the lower part of the subsoil.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the natural medium for the growth of land plants. Functionally, its most important property is its productivity for plants; morphologically, its dominating feature is its profile; and geographically, it is significant in that the distribution of each soil type is limited by definite processes. The soil represents the sum total result of all the physical, chemical, and biological forces that have combined to produce it. According to Marbut (*30, p. 11*):

> Soils are the products of the environmental conditions under which they have developed or are developing. These conditions in turn are the products of geologic, topographic, physiographic, climatic, and biologic factors.

Puerto Rico is a little smaller than Connecticut and a little larger than the combined areas of Lincoln and Hayes Counties, Nebr., and, as it has a nearly uniform tropical temperature, one might naturally expect only a few different soil series. This is not the case, however, owing to the wide range of differences in other environmental conditions. Because of great differences in rainfall, relief, vegetation, and parent rock there are many distinct combinations of the factors responsible for soil development. There are 358 soil types, phases, and miscellaneous land types recognized on the island. This represents a total of 115 soil series. Comparing this number with the 62 soil types and phases from 19 soil series mapped in Lincoln and Hayes Counties, Nebr., a person can visualize the contrasting differences in the two areas.

Soil series that have the same general type of profile are grouped in higher categories to make up the great soil groups. In Puerto Rico several of the great soil groups include a number of soil series, differing from one another in important features, owing to differences in parent material, relief, and age, but all having similar profiles. Some groups include only one or two soil series.

The great soil groups can, in turn, be placed in three orders: (1) Zonal, (2) intrazonal, and (3) azonal soils, as defined by Baldwin and others (*3*). The development and significance of the great soil groups of the United States are concisely presented by Marbut (*30*) and Kellogg (*23*). The zonal order includes those great groups of soils having well-developed soil characteristics that reflect the influence of the active factors of soil genesis—climate and vegetation. These characteristics are best developed on the gently undulating (but not level) upland with good drainage, from parent material not of extreme texture or chemical composition that has been in place long enough for the biological forces to have expressed their full significance. Except where the continuity of the landscape is interrupted by mountains or large bodies of water, these soils occur over large areas, or zones, limited according to their own geographic characteristics. Owing to the mountain barriers that influence the climate, the zones are very narrow compared with those in the United States, as shown in figures 133 and 134.

The intrazonal soils include those groups of soils with more or less well developed soil characteristics that reflect the dominating influence of some local factor of relief or parent material over the normal effect of climate and vegetation.

The azonal soils include those groups of soils without well-developed soil characteristics, owing to their youth or to conditions of parent material or relief that prevent the development of definite soil characteristics.

Most of the important soil groups occurring in the United States are fairly well represented by one or more soil series in Puerto Rico. The important groups of soils occurring in Puerto Rico and discussed hereafter may be outlined in respect to these three classes as follows: (1) Zonal, including the Gray-Brown Podzolic, Red and Yellow Podzolic, Reddish-Brown Lateritic, Yellowish-Brown Lateritic, Laterite, Reddish Prairie, Chernozem, Reddish Chestnut, Reddish Brown, and Red Desert soils; (2) intrazonal, including the Rendzina, Planosol, Ground-Water Podzol, Ground-Water Laterite, Wiesenböden, Half-Bog, Bog, Solonchak, and Solonetz soils; and (3) azonal, including the Alluvial soils and Lithosols, and Sands (Dry).

These groups may be defined as follows:

Gray-Brown Podzolic.—Zonal group of soils having a comparatively thin organic-mineral layer over an acid grayish-brown leached layer resting on an illuvial yellowish-brown, reddish-brown, or grayish-brown horizon. Developed under forest in a humid climate. The members of this group are not so well defined as those in continental United States, and many are in transition with soils of the following group.

Red and Yellow Podzolic.—Zonal group of soils having a comparatively thin organic-mineral layer over a highly leached grayish-brown, light-brown, or brownish-gray horizon resting on a compact or plastic acid red (Red Podzolic soil) or yellow (Yellow Podzolic soil) layer, and this, in turn, on a red, gray, and brown reticulately mottled horizon. Developed under a thick stand of forest vegetation in humid or subhumid warm climates.

Reddish-Brown Lateritic soils.—Zonal group of soils having reddish-brown or dark reddish-brown organic and organic-mineral layers over reddish-brown leached layers resting on illuvial red or purplish-red permeable horizons. Developed under humid tropical climate.

Yellowish-Brown Lateritic soils.—Zonal group of soils having brown friable clayey surface soils overlying yellowish-brown or brownish-yellow friable clay subsoils with a very high percentage of colloid, underlain by a fairly permeable yellow or reddish-yellow horizon. Developed under humid tropical climate.

Laterite soils.—Zonal group of soils having a reddish-brown organic-mineral layer above a thick permeable and friable impoverished red or purplish-red soil, which imperceptibly grades into highly weathered neutral red material. Developed under a tropical forest in a hot moist climate.

Reddish Prairie soils.—Zonal group of soils having a very dark brown slightly to moderately acid surface horizon, which grades through a brown or reddish-brown neutral soil to a lighter colored parent material. Developed under open grassy forest in a subhumid climate.

Chernozem soils.—Zonal group of soils having nearly black fairly thick granular alkaline surface soils, which grade into yellowish-brown or light-colored alkaline soils resting on a layer of lime accumulation. Developed under thick stand of grasses and scattered trees in a warm subhumid climate. Much of the tropical Chernozem has a somewhat red tint, particularly just above the lime accumulation.

Reddish Chestnut soils.—Zonal group of soils having a dark-brown granular alkaline surface horizon, which grades below into lighter reddish-brown or yellowish-brown strongly alkaline soil and finally into a zone of lime accumulation. Developed under a fairly thick stand of grasses in semiarid climate. The yellowish-brown or reddish-brown horizon is heavier in texture than the material above or below it.

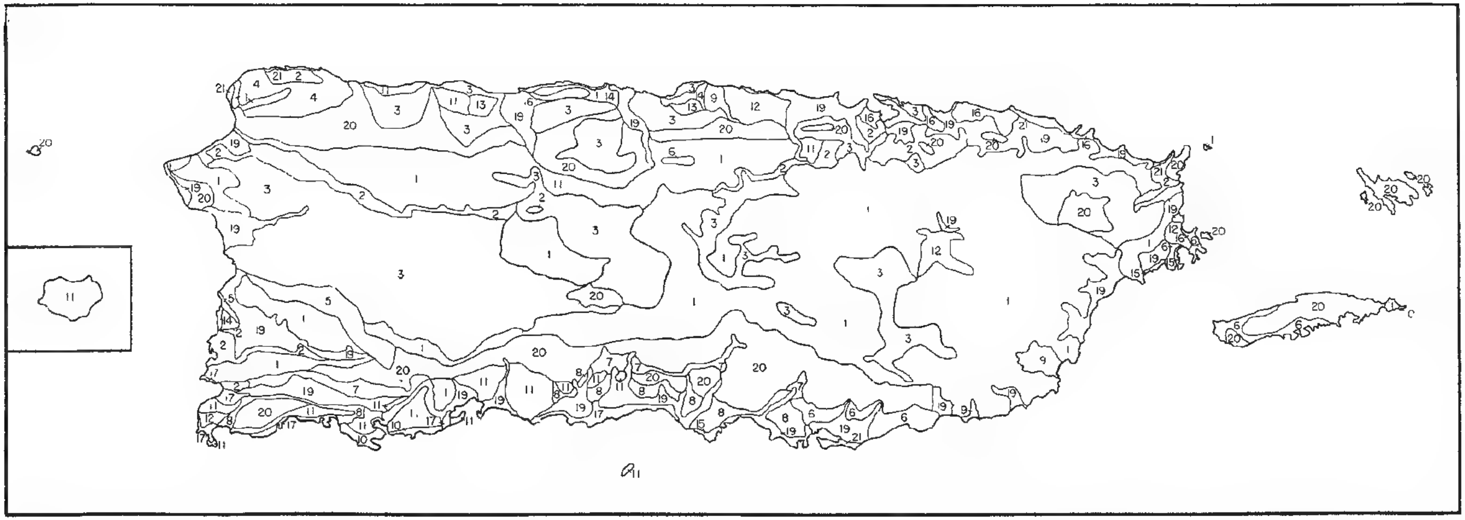

FIGURE 134.—General distribution of the important soils in Puerto Rico: 1, Gray-Brown Podzolic; 2, Red and Yellow Podzolic; 3, Reddish-Brown Lateritic; 4, Yellowish-Brown Lateritic; 5, Laterite; 6, Reddish Prairie; 7, Chernozem; 8, Reddish Chestnut; 9, Reddish Brown; 10, Red Desert; 11, Rendzina; 12, Ground-Water Laterite and Planosol; 13, Ground-Water Podzol; 14, Wiesenböden; 15, Half-Bog; 16, Bog; 17, Solonchak; 19, Alluvial; 20, Skeletal and Lithosol; and 21, Dry Sands.

Clasificación científica general de los suelos de Puerto Rico.

Reddish Brown soils.—Zonal group of soils having a light-brown moderately to strongly alkaline or calcareous surface horizon, which grades, through a light reddish-brown horizon, into lighter colored calcareous soil and rests at a rather slight depth on a thick layer of accumulated lime. Developed under a sparse vegetation, mostly grasses. Where the parent materials are strongly calcareous, the reddish-brown color is less noticeable or is lacking. Such a soil approaches the dry-land Rendzina in character.

Red Desert soils.—Zonal group of soils having a reddish-brown thin organic-mineral layer over red neutral material which, in Puerto Rico, grades into calcareous parent material. Developed under a very scant shrub vegetation. Some of these soils probably would be classed with some of the Terra Rossa of the Mediterranean region.

Rendzina soils.—Intrazonal group of soils with granular neutral or calcareous surface soils ranging from brown to black, depending on the average annual precipitation and thickness of vegetal cover, underlain by a thin yellowish-brown calcareous layer that grades into gray or white highly calcareous parent material. Developed under grass vegetation or mixed grasses and forest. In some of these soils the black or dark-brown layer directly overlies the calcareous parent material.

Planosols.—Intrazonal group of soils with eluviated surface horizons underlain by illuviated B horizons that are more strongly cemented or compacted than in the associated normal zonal soils. Developed on nearly flat relief under grass or forest vegetation in a humid, subhumid, or semiarid climate. Sometimes called claypan and hardpan soils.

Ground-Water Podzols.—Intrazonal group of soils having a thin organic layer over a strongly leached light-gray sandy layer, which rests on a black or reddish-brown organic or iron hardpan (orterde or ortstein). Developed on imperfectly or poorly drained sandy materials in humid climates.

Ground-Water Laterite.—Soils having a gray-brown surface layer over a leached yellowish-gray subsurface layer overlying a reticulately mottled cemented hardpan or concretional layer, which continues to a depth of several feet. Typically, hardpan occurs at a depth of 1 foot, except in eroded areas. Some concretions are in the surface soil.

Wiesenböden soils.—Intrazonal group of imperfectly or poorly drained soils with dark grayish-brown or black surface soils high in organic matter, grading at depths ranging from 6 to 20 inches into gray horizons. Developed under grasses, sedges, or open swamp forest.

Half-Bog soils.—Intrazonal group of soils with muck or peaty surface soils underlain at slight depths by gray mineral soils. Developed under swamp-forest type of vegetation.

Bog soils.—Intrazonal group of soils with muck or peaty surface soils underlain by deep peat. Developed under swamp or marsh type of vegetation.

Solonchak soils.—Intrazonal group of soils having a high concentration of soluble salts, especially in the surface soil, which is light colored. Developed in barren areas and under salt-resistant vegetation usually in arid to subhumid climates.

Solonetz soils.—Intrazonal group of soils having variable surface horizons underlain by dark hard soil with columnar structure, generally highly alkaline. Developed under grass and shrub vegetation, mostly in arid or subhumid climates.

Alluvial soils.—Azonal group of soils developing from recent alluvium and subject to alterations during overflows.

Lithosols.—Azonal group of soils having little or no clearly expressed soil morphology and consisting of freshly and slightly weathered masses of rock fragments. Largely confined to steeply sloping land.

Sands (Dry).—Azonal group of soils having no clearly expressed morphology and consisting of well-drained sand deposits.

A classification of all the soil series in Puerto Rico, according to soil groups, is shown in table 16. Many of the soil groups exist in complex patterns, and there are transitional soils that have some characteristics of the soils of two or more groups. Either all the soil types in the series or one or more of the phases have such characteristics. For example, the Cayaguá series has been classified with the Gray-Brown Podzolic

soils group, but the steep phases approach the group of Lithosols. Small areas of the Jácana soils as mapped have characteristics of the Reddish Chestnut soils group as well as of the Chernozem and the Reddish Brown soils groups. Some of the steeper parts approach the Lithosols in character. In these instances the soil series is placed within the group in which it most nearly fits, with a number or numbers in parentheses following the series name to indicate that areas included with it on the map have some characteristics corresponding to the soil group or groups as indicated.

TABLE 16.—*Classification of the soil series in Puerto Rico according to soil groups*

Zonal soils					
1.[1] Gray-Brown Podzolic	2. Red and Yellow Podzolic	3. Reddish-Brown Lateritic	4. Yellowish-Brown Lateritic	5. Laterite soils	6. Reddish Prairie
Cayaguá (21).[2] Ciales. Humacao. Juncos. Las Piedras. Mariana (21). Naranjito (21). Plata (21). Sabana (21). Teja. Utuado (21). Vía.	Cabo Rojo. Fajardo. Jayuya (21). Lares. Los Guineos (2) (21). Moca. Río Arriba. Vega Alta.	Alonso (21). Bayamón (5). Catalina (5) (21). Cialitos (21). Islote (2). Malaya (5) (21). Matanzas (5). Maleza (2). Río Lajas. Río Piedras (2). Torres (2).	Almirante. Coto. Espinosa.	Nipe.	Amelia. Arcadia. Barrancas. Daguao (21). Dominguito (2) Llave. Mabí (1). Machete. Paso Seco. Resolución. Vives.

Zonal soils—Continued				Intrazonal soils	
7. Chernozem	8. Reddish Chestnut	9. Reddish Brown	10. Red Desert	11. Rendzina	12. Planosol
Camagüey. Coamo (8). Ponceña. Río Cañas (8). Santa Clara (11).	Fé (17) (18). Fraternidad (7). Juana Díaz. Mercedita (17) (18).	Jácana (7) (8) (21).	Ensenada (21). Pozo Blanco (9).	Aguilita (*9*)[3] (21). Colinas (*1*) (21). Portugués (*7*). San Germán (*9*) (21). Soller (*3*) (21). Yauco (*7*).	Candelero (*2*). Guayabo (*2*). Sabana Seca (*2*). Santa Isabel (*8*).

Intrazonal soils—Continued						
13. Ground-Water Podzol	14. Ground-Water Laterite or Planosol	15. Wiesenböden	16. Half-Bog	17. Bog	18. Solonchak	19. Solonetz
Algarrobo (*2*). Corozo (*2*).	Caguas (12) (*2*) Sabana Seca (*2*)	Guánica (*8*). Maunabo (*1*). Palmas Altas (*1*). Piñones (*1*).	Peat, shallow phase (*1*). Reparada (*8*). Saladar muck, shallow phase (*1*). Ursula (*8*).	Peat (*1*) (*9*). Saladar muck (*1*) (*9*). Tiburones muck (*1*).	Cintrona (*9*) (*8*) (15). Serrano (*8*) (*9*) (15).	Teresa (*8*) (*9*).

See footnotes at end of table.

TABLE 16.—*Classification of the soil series in Puerto Rico according to soil groups*—Continued

Azonal soils		
20. Alluvial	21. Lithosols and shallow soils	22. Sands (Dry)
Aguirre (*8*). Altura (*7*). Coloso (*1*). Córcega (*1*). Estación (*1*). Fortuna (*1*). Irurena (*1*). Josefa (*1*). Martín Peña (*1*) (*2*). Mayo (*1*). San Antón (*8*). Talante (*1*). Toa (*1*). Vayas (*8*). Vega Baja (*1*) (*2*). Viví (*1*). Yabucoa (*1*) (14) (16) (17).	Descalabrado (*6*) (*7*) (*8*) (*9*). Guayama (7) (*8*). Lajas (*3*). Múcara (*1*) (*6*). Pandura (*1*). Picacho (*1*). Rosario (*5*). Rough stony land (*1*). Tanamá (*3*). Vieques (*6*). Yunes (*1*).	Aguadilla (*1*). Cataño (*1*). Coastal beach (*1*). Dune sand (*1*). Jaucas (*9*). Meros (*9*). Palm Beach (*1*). Riverwash. St. Lucie (*2*).

[1] Nos. 1 to 22 indicate soil groups.
[2] Arabic numbers in parentheses indicate the additional soil group in which some type, phase, or mapping inclusion of the series may also be classified or with which it is in transition.
[3] Italic numbers in parentheses after the soil series in the intrazonal and azonal soil groups indicate the zonal soil group with which the soil series is associated.

Intrazonal and azonal soils occur throughout the various zonal soils areas. Italic numbers in parentheses following the soil series name indicate the corresponding zonal soil group with which the soil series is most closely associated.

The Ground-Water Podzols owe their development largely to the sandy character of their parent materials and to the high rainfall. The soils classed as Gray-Brown Podzolic owe their development partly to the character of the parent material and more largely to the fact that they have been kept fairly young by rapid geological erosion. They do not correspond in all points to the Gray-Brown Podzolic soils of continental United States.

Probably the principal reason for so many soil groups in so small an area is the differences in climate, which is responsible for the evolution of many of the soil series on the island. The mean annual rainfall ranges from about 20 inches along the arid southwestern coast to about 200 inches in the high rocky Sierra de Luquillo in the northeastern part (fig. 34).

This wide range of yearly precipitation can be divided logically into seven rather distinct rainfall belts, each of which is related to important soil characteristics, as shown in table 17. The evaporation far exceeds the rainfall in the arid districts, and this, combined with the effect of the trade winds fanning the island during the day, land breezes at night, and subtropical temperatures, tends to make a drier soil climate than the rainfall indicates. The vegetation and soils in a belt where the rainfall ranges from 20 to 30 inches, are comparable to a 10- to 15-inch rainfall belt in southwestern United States. Irrigation is practiced, especially for sugarcane, in areas receiving less than 50 inches of annual rainfall. In some areas irrigation has proved profitable, even where the yearly rainfall is as much as 60 inches.

TABLE 17.—*General characteristics of rainfall belts in Puerto Rico*

Rainfall (inches)	Plants	Growth of vegetation	Soil erosion	Soil color	Dominant zonal and intrazonal soil groups	Elevation	Density of rural population
						Feet	
20-25	Xerophytic	Very slow; sparse	Very slight	Red	Red Desert, Reddish Brown.	0- 100	Very sparse.
25-35	do	Slow; sparse	Slight, some gullies	Brown	Reddish Chestnut, Solonchak, Solonetz.	0- 500	Sparse.
35-45	do	Moderate in valleys; sparse on hills.	Some gullies	Dark grayish brown and black.	Chernozem	0- 700	Fairly dense.
45-60	Xerophytic on hills; mesophytic in valleys.	Fairly rapid	Severe sheet erosion on cultivated hillsides.	Very dark grayish brown and red.	Chernozem, Reddish-Brown Lateritic, Reddish Prairie, Yellowish-Brown Lateritic.	0-1, 500	Dense.
60-75	Mesophytic	Rapid	Slight	Grayish brown	Gray-Brown Podzolic, Ground-Water Podzol, Planosol, Reddish-Brown Lateritic, Bog.	0-1, 500	Very dense.
75-95	do	do	do	Red and black.	Reddish-Brown Lateritic, Red and Yellow Podzolic, Laterite, Rendzina.	80-2, 000	Fairly dense.
95-160+	Rain-forest and moss vegetation.	Extremely rapid	Moderate on cultivated hillsides.	Grayish brown	Reddish-Brown Lateritic, Red and Yellow Podzolic.	2, 000-4, 390	Sparse.

Extremes in rainfall are just one of the many variable features of the island. Many types of vegetation are produced. Some of the most important are: Xerophytes in the arid districts; mesophytes, and many epiphytes in the rain forest, in humid areas; bryophytes on the fog-laden wind-swept mountain peaks; hydrophytes in the marshes; and halophytes on the saline and alkali soils near the coast. Most of the original native vegetation has been destroyed or seriously disturbed, but its effect on soil development is still visible.

The topography as a whole ranges from level to precipitous. This same range in topography occurs in each rainfall belt, and the number of soil types and phases is thus increased greatly.

The imprint of the parent rocks on soil development is as striking as in nearly any other part of the world. The rocks include representatives of the three major groups—igneous, sedimentary, and metamorphic. The principal rocks include several types of Tertiary and Cretaceous limestone, many kinds of shales, volcanic ash, tuff, lava, granite, sandstone, serpentine, and conglomerates. As most of these rocks occur within several rainfall belts and have many different gradients of slope, the number of soil series is proportionally larger than if each kind of rock were centralized in one rainfall belt and on one type of relief.

The age of the soils ranges from the embryonic stages of some of the peats to the ferruginous Laterite derived from serpentine, metamorphosed from peridotites.

Other factors that have a minor influence in soil development are elevation, length of time the land has been in cultivation, density of population, quantity of soil amendments used, and degree of normal and accelerated erosion. The elevation ranges from sea level to 4,398 feet above. The density of population ranges from nearly 0 to more than 600 people to the square mile. The period of cultivation ranges from that of virgin areas to nearly 380 years of continuous farming. The application of fertilizer ranges from nil to 1,500 pounds to the acre on the same soil type. The effect of erosion ranges from that seen on adequately controlled densely covered grassy areas to that of the bare landslips, gullied spots, and improperly farmed steep hillsides.

Owing to sudden changes, within short distances, of the factors responsible for soil development, Puerto Rico is a nearly ideal place in which to study the morphology and genesis of soils. Because of the great importance of soil to the people, the island is also a good place in which to observe the relationship between soil types and land use. Figure 135 shows the relationship of the soil types to elevation, relief, and parent material from a point along the north coast to a point along the south coast. It readily may be seen that there are many soil types and that they are very closely related to relief, elevation, and parent material. Figure 136 shows the relationships of the mean annual rainfall, depth of unconsolidated soil material, and the most important crops. This sketch is made from the identical areas as those in figure 135, and it shows that the semiarid and arid southern hills are more rounded than the hills on the humid north side of the mountain crest. There is a very close correlation between soil types and principal agricultural crops. Sugarcane is grown on the level areas, subsistence crops on the steep shallow soils, coffee on the south slopes of the deep soils receiving a high mean an-

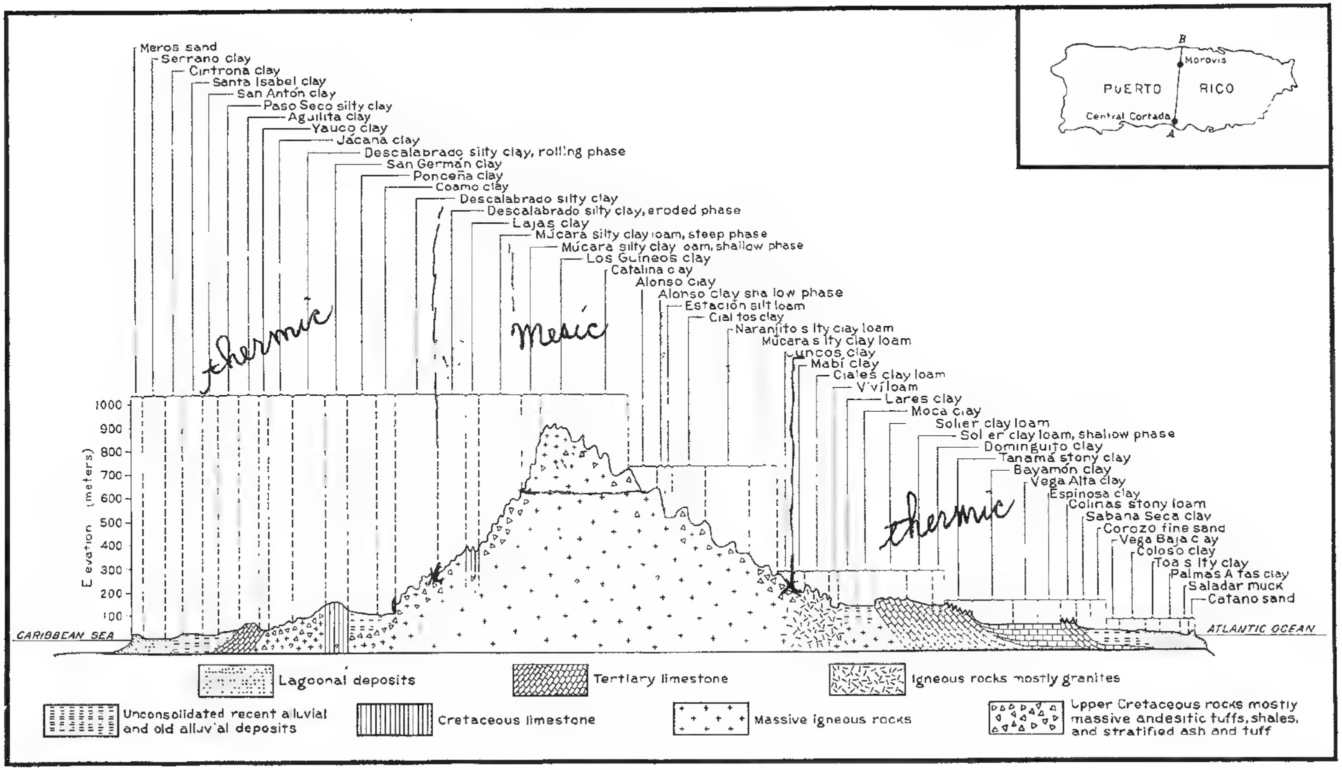

FIGURE 135.—Cross section of Puerto Rico, indicating soil types in respect to elevation, relief, and parent rocks. The hypothetical line passes through Morovis and Central Cortada.

Sección transversal de Puerto Rico indicando tipo de suelo con relación a elevación, relieve, y rocas madres. La linea hipotética pasa por Morovis y Central Cortada.

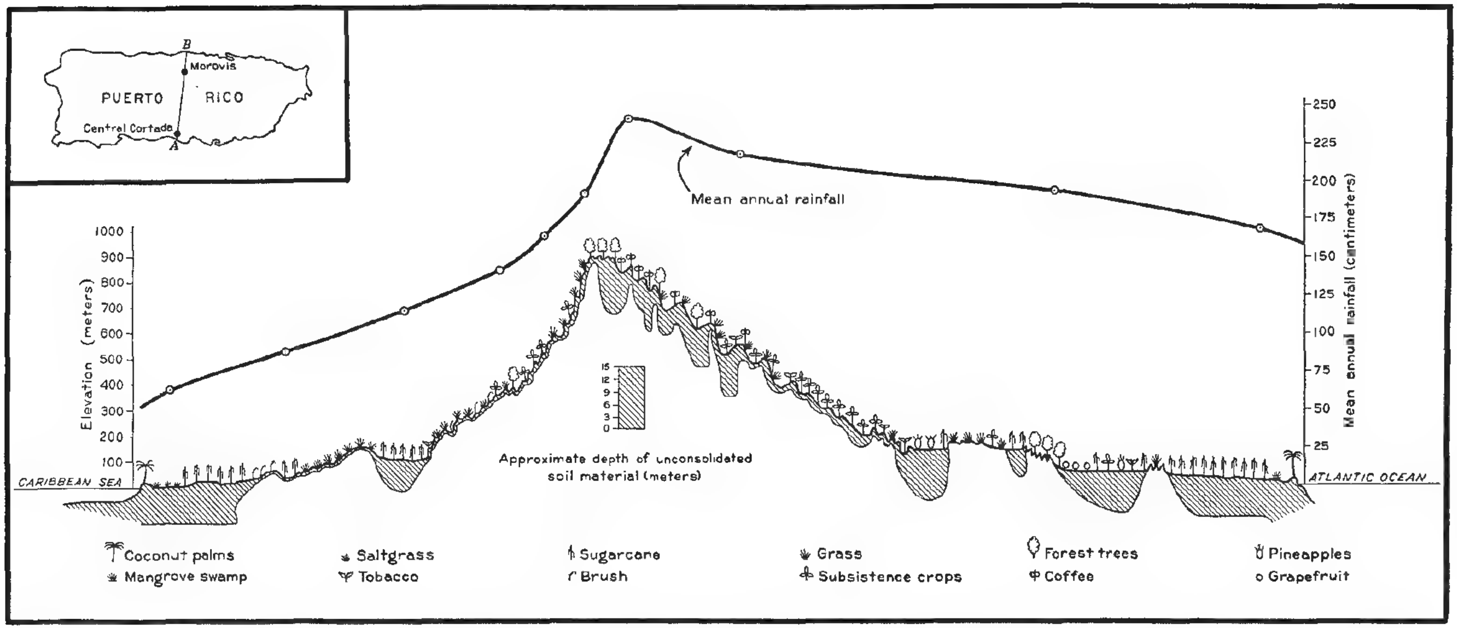

FIGURE 136.—Cross section of Puerto Rico, indicating elevation, depth of soil and unconsolidated rock, mean annual rainfall, and vegetation.

Sección transversal de Puerto Rico indicando elevación, profundidad del suelo y roca no consolidada, precipitación pluvial anual, y vegetación.

nual rainfall, and coconuts along the coast. Grapefruit is grown on level soils at low elevations.

It may be seen that the Los Guineos soils occur at high elevations, receive a high annual precipitation, have very deep soil material, and are used for forest and coffee.

The mean annual rainfall gradually increases from 60 inches along the northern coast to 95 inches near the mountain crests, then drops rapidly to 20 inches along the Caribbean Sea.

A soil scientist can predict within reasonable limits the kind of soil that will be developed if he knows the relief, the climate, the parent rock, and something about the original vegetation. If he knows the characteristics of the soil and the rooting habits and other requirements of the plants, he can predict generally what plants are adapted to the soil. He cannot state precisely, however, the best use for each particular parcel of land unless he studies the area thoroughly with regard to economic conditions as well as soils and crops.

The soil scientist must make due allowance for the increased intensity of climatic action in comparing the morphology and genesis of the soils of Puerto Rico with most of the soils in continental United States. The mean annual temperature of this frost-free island is about 71° F., and the mean annual rainfall is about 70 inches. In comparing this to northern Ohio, which has a mean annual temperature of about 50° and a mean annual precipitation of 36 inches, one may reasonably expect weathering and soil formation to be from 7 to 10 times faster in Puerto Rico. This means that, in relation to time required for equivalent development of soils in Puerto Rico, centuries shrink to decades, decades to years, and years to months.

Each of the seven rainfall belts is a more or less definite pedologic region. The outstanding characteristics of each region will be discussed, and a few of the most important profiles will be described in detail.

THE 20- to 25-INCH RAINFALL BELT

The least extensive belt is the most arid one, which has an average annual rainfall between 20 and 25 inches. This belt covers a small area of Tertiary limestone hills in the southwestern part of Puerto Rico, the eastern tip of Isla de Vieques, and Isla de Caja de Muertos. Tuffaceous rocks outcrop in a few places. The clear hot days, warm bright nights, and nearly continuous wind movement cause low humidity and excessive evaporation. This naturally affects the soil climate. Vegetation is determined by the soil climate, and within certain limits soil temperature and soil moisture are determined by vegetation. In this rainfall belt, the soils generally are dry, and therefore the vegetation is mostly xerophytic and sparse. The spaces between the areas covered by vegetation are wide and barren, but not to the same degree as in the Desert soils of the United States as described by Lapham (*28*) and Nikiforoff (*32*).

The barren dry areas generally become much hotter during the day than the surrounding air, and at night they radiate heat and generally have a lower temperature than the air over the densely covered grassed areas. According to Vageler (*47, p. 104*), the daily amplitude of temperature changes of the surface soil in barren dry areas in the subtropics may be as much as 60° to 80° C., which far exceeds corresponding variations in temperate climates. These

extremes in daily temperature are partly responsible for the inactivity and lack of micro-organisms in the soil to a depth of 12 or 15 inches. In the nonirrigated arid soils the activities of worms and micro-organisms are confined to depths where the daily variations in temperature are not so great and where the soil contains moisture in excess of the wilting coefficient. The lack of biological activity probably is responsible to some extent for the scarcity of microflora. With but few exceptions, however, soil moisture is the limiting factor in both plant and animal life in the soil. Most of the vegetation consists of gray woody perennial shrubs, cacti, and other thorny plants, which add only a small amount of leaves to the soil, and there seems to be a critical deficit of green vegetation and organic matter. Organic acids from the decomposition of plant remains also are lacking or are of little significance. The deficiency of organic acids and other chemical activity, owing to the small amount of soil moisture, prevents rapid weathering of the rocks, and soil development is slow. The residual soil material is very shallow, contains a high percentage of bases, and generally is alkaline or calcareous, depending on the parent rock.

Soils in the 20- to 25-inch rainfall belt derived from tuffaceous rocks in general are alkaline, shallow, brown, and granular. The depth to parent rock depends on the slope, but even in nearly level or slightly undulating areas the soil material above the parent rock seldom exceeds 10 inches in thickness. Pedologically, these soils are grouped with the Reddish Brown soils, but, owing to their very small extent, they have been included in mapping with Jácana clay, a soil classified with the Reddish Chestnut soil group and typically occurring in rather extensive areas in the 30- to 35-inch rainfall belt.

The effect of the soil-forming processes on the transformation of limestone to soil seems to be different from the effect on the transformation of tuffaceous rocks to soil. Regardless of the degree of hardness of the tuff or the quantity of soil moisture, the immature soils derived from tuff are brown or yellowish brown, but as they develop the color changes. The color of the surface soil of the developed soil changes gradually with increasing soil moisture from light brown to chestnut brown, black, very dark grayish brown, grayish brown, and reddish brown or red; corresponding, respectively, to the six soil groups, Reddish Brown, Reddish Chestnut, Chernozem, Reddish Prairie, Red Podzolic, and Reddish-Brown Lateritic.

Judging from evidence of the weathering of many kinds of limestone within the several rainfall belts, the character of the immature as well as of the developed soil depends on the rapidity of the weathering of the limestone, which in turn depends on the hardness of the rock and the biochemical activity.

Soft marly limestone weathers fast enough to allow the development of a plastic alkaline granular soil in either the arid or the humid sections. The immature soil is grayish brown or yellowish brown. The color of the A horizon of the well-developed soil ranges from light grayish brown in the arid sections to black in the humid sections. The biological pressure and organic content are exceedingly high in the humid sections and gradually become less toward the arid sections.

The hard Cretaceous limestone weathers so slowly that in any rainfall area the soil produced is red or reddish brown and is permeable. In the arid sections, Red Desert and Terra Rossa soils are produced.

They are about neutral in reaction and have a higher content of bases but less humus than do soils from similar rock in humid districts. The general characteristics of the immature soils and the well-developed soils are very similar. A profile of a well-developed soil shows very little morphological difference from the surface to the parent rock. The red slightly acid soil invariably lies directly on gray or white crystalline limestone rock. Medium-hard Tertiary limestone develops into black plastic Rendzinas in the humid districts, probably because the combination of high precipitation and high temperature accelerates the biochemical activity to the point where the limestone is weathered rapidly. In the arid districts the intensity of heat and the dry atmosphere undoubtedly have a hardening effect on the limestone, thereby increasing its resistance to weathering. Then, too, owing to lack of soil moisture, the biochemical activity is reduced to such an extent that the rock weathers slowly, leaching keeps pace with decomposition and disintegration, and, therefore, red slightly acid permeable soils are developed.

Within the very small extent of the 20- to 25-inch rainfall belt only a very few soils occur. In addition to the areas of Jácana clay, most of the other areas are occupied by some type or phase of the Ensenada series. The best developed soil of this area is Ensenada clay (fig. 16). It is a Red Desert or Terra Rossa soil developed from limestone in level well-drained areas sparsely covered with xerophytic vegetation, such as pricklypear, turkscap, button sage or Santa María, blackbead or escambrón, and many other plants. Internal drainage is very good. A profile of Ensenada clay was observed south of Ensenada where the mean annual rainfall is 29.35 inches, the annual rainfall ranging from 11.34 to 53.07 inches; the mean annual temperature is 77.2° F., the temperature ranging from 51° to 100°; and the elevation is about 450 feet. A description of the profile examined follows.

0 to 4 inches, dark-red permeable fragmentary faintly plastic neutral clay. This material is generally dry, very resistant to pressure, and when crushed becomes somewhat lighter red, indicating that there is some organic matter present, probably heavily masked by the bright color of the iron compounds. The content of organic matter is much less than in similar soils in humid sections.

4 to 15 inches, dark-red permeable faintly fragmentary nonplastic neutral clay. The material in this layer is slightly resistant to pressure, and, although dark red, it is not so red as that in the layer above. The color of the material in the two layers, when crushed, is nearly identical. Without any visible morphological gradation this layer rests on the pinkish-white Tertiary Ponce limestone.

Table 18 shows the results of mechanical analyses of samples of Ensenada clay.

TABLE 18.—*Mechanical analysis of Ensenada clay* [1]

Sample No.	Depth	Fine gravel (2–1 mm.)	Coarse sand (1–0.5 mm.)	Medium sand (0.5–0.25 mm.)	Fine sand (0.25–0.1 mm.)	Very fine sand (0.1–0.05 mm.)	Silt (0.05–0.005 mm.)	Clay (0.005–0 mm.)
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
581456	0–4	0.3	2.1	3.1	9.3	6.9	38.4	39.9
581457	4–15	.1	.8	1.5	5.3	4.0	32.3	56.0

[1] Analyst, T. M. Shaw, formerly assistant physicist, Division of Soil Chemistry and Physics, Bureau of Plant Industry.

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There is no evidence whatever of accumulated calcium carbonate in the solum. This is probably due to two causes—(1) the soil is so permeable that the soluble calcium carbonate is readily leached, and (2) the perennial shrubby vegetation is not a heavy feeder of lime, although its roots penetrate the rock. When fallen leaves and twigs are incorporated in the soil they add a very small quantity of lime, compared with the amount that would be added by a dense grass vegetation.

On most of the steep hillsides in the vicinity the parent rock is exposed, and on many of the nearly level or undulating areas the material above the rock is less than an inch thick. In some places small circular and irregular-shaped cavities 2 feet deep in the limestone are filled with red permeable clay. This soil grades into the shallow dark grayish-brown alkaline Aguilita soils in the more moist districts.

THE 25- TO 35-INCH RAINFALL BELT

The western part of the 25- to 35-inch rainfall belt includes an area that consists topographically of round-topped rolling or steep limestone hills separated by intermittent streams. The streams are flanked on either side by alluvium, which grades into alluvial fans that terminate abruptly against the limestone hills. The eastern part of the area consists mostly of wide playa plains traversed from north to south at intervals of about 4 miles by intermittent streams. Narrow ribbonlike bands of sandy alluvium lie close to the banks. Farther from the channel the texture of the alluvium becomes heavier, finally grading into heavy alluvial-fan materials that extend, in places, from the banks of the coast to the mouths of the canyons whence the material has been flushed. Many of the alluvial fans are triangular or fan-shaped, with the apex terminating at the head of the stream, and many adjacent ones coalesce to form a broad belt of alluvium between the hills and the sea.

The rainfall, although scant compared with that in most other parts of the island, often comes in torrents. The intensity of rainfall may exceed 1 inch in 10 minutes. The run-off is exceedingly high, especially at the beginning of the rainy season on the rather steep slopes of the sparsely grassed hillsides. At this time of the year (about June) it is not uncommon to see walls of turbid water rushing down the stream beds which a few hours before were bone dry. The force of the water carries large rocks far down the stream channel. At the mouths of the streams, unassorted drift, consisting of boulders, rock fragments, sand, silt, and clay, is spread over the level land. The heavy and larger material is deposited first, and the silt and clay are carried far from their source. What has been destructive to the hillsides has been constructive to the playa plains. At present the alluvial fans, such as those composed of the Paso Seco, Fé, and Santa Isabel soils, have been built up to such an extent that they are seldom if ever overflowed, and they are highly productive for sugarcane. The deposition is confined to the alluvial plains, such as the azonal San Antón and Altura soils, which are also exceedingly productive when properly fertilized and irrigated—more so than any other soils on the island.

The run-off is probably higher in proportion to the precipitation than in the humid districts, and erosion on the hillsides is very notice-

able at times, yet the hills have not been defaced nearly so much as those in the humid districts. The hills in the arid and semiarid districts are rounded, rather than ∧-shaped as in the humid districts. The depth of the soils to parent rock on the hillsides in the two districts is greatest in the high rainfall areas, as decomposition in these areas is much faster, owing to more biochemical activity, and often keeps pace with erosion, even on steeply cultivated hillsides.

Skirting the coast, the playa plains in many parts of the 25- to 35-inch rainfall belt are subject to wash during high tide. The vegetation on the water-saturated soils is, as might be expected, more in accord with humid than with arid climates, and the soils developed are hydromorphic equivalents of the normal soils in extremely wet climates.

The mangrove climax is dominant along narrow irregular-shaped swamps adjacent to the coast and in protected bays as well as on chains of tiny islands extending one-half mile into the open sea. The thousands of interlaced stiltlike roots of the mangroves provides a nearly ideal barrier to the agitation of the waves, and the silt-laden waters flowing from the interior soon lose their load of silt around the roots. The small amount of mineral soil, in addition to the rapidly forming mangrove roots and continuously falling leaves and twigs from this evergreen shrub, ultimately build an organic soil above the tide, and another area is wrested from the sea.

The development of peat from mangroves, as discussed by Dachnowski-Stokes and Roberts (*13*), is as follows:

0–101.6 centimeters. Brown to reddish-brown, coarse but firm fibrous peat, consisting chiefly of a porous, interlacing network of fine rootlets, yellowish-brown in color, brittle when dry, crumbling into small particles. Embedded in the tangle of rootlets are relatively small quantities of dark-colored, finely divided organic and mineral sediments carried by tides and waves of sea water. A prominent feature is considerable amounts of stout roots of mangroves, the pith of which is in varying stages of decomposition. The whole profile section is indistinctly differentiated, free from woody fragments, * * * and is but feebly altered by soil-making processses; it is the product of the roots and rootlets from a pure stand of mangrove. Soluble salts are present in the entire profile in amounts ranging between 3 and 5½ percent, and the reaction of the air-dried organic material is strongly acid (pH 4.3–4.6). The thickness of the layer varies in places from 1 to 1½ meters and rests abruptly on coarse white sand of unknown depth.

Associated with peat in all the coastal mangrove swamps of the island are muck and peaty muck in advanced stages of decomposition. The thickness of the organic materials varies from place to place. The material in all areas is acid, and, unless the land is adequately drained, it contains harmful quantities of sodium chloride. The drained areas are used fairly extensively for the production of sugarcane. Yields range from 35 to 40 tons an acre, but the content of sucrose is very low. The principal occupation on the undrained areas is the gathering of mangrove wood for the making of charcoal.

Many of the old estuaries and lagoons have been filled in by alluvial material encroaching on the sea. These deposits at or near sea level are vulnerable to harmful soluble salts. The content of salts generally decreases with an increase in elevation and lateral distance from the source of the brackish water, although some saline areas occur as seepage spots far back in the playa plains, generally at the base of irrigated hillsides or several hundred yards below an unlined irrigation

canal. The geobotany of these saline soils ranges from barren snow-white flat areas containing about 4 percent of salt in the surface soil, through barilla thickets on 1- to 3-percent salt flats, to the Bermuda and horquetilla grass pastures containing from 0.2 to 1 percent of salt. Areas containing 0.2 percent of salt may show efflorescence on the surface of the soil or on ditch banks.

The morphological characteristics of the barren areas are nearly identical with the intrazonal soil group known as Solonchak, as described by Kellogg (*24*). The surface soil to a depth of about 1 inch is fluffy, soft, and loose. In places thin crusts of salt are formed on the immediate surface. At a depth between 2 and 4 inches the material is gray and vesicular and readily breaks when dry into a loose fluffy powder. This layer has a high percentage of salt crystals. It changes abruptly to a firm somewhat compact heavier textured layer which, in many places, is slightly pinkish brown and contains pockets of salt crystals. The material in this layer gradually becomes blue gray as the mean level of the fluctuating water table is reached. This profile is calcareous from the surface downward, and much of the lime comes from small sea shells or broken shell fragments. Similar profiles in humid districts along the north, east, and west coast are neutral or acid in reaction. The Serrano soils are the best examples of Solonchak along the south coast. Some areas of Piñones clay, peaty-subsoil phase, are good examples along the north and east coast. Neither soil has high biological activity.

Soils sufficiently low in salt for the growth of a dense mat of grass lack the characteristics of Solonchak, and most of them have an azonal or zonal profile.

Closely associated with the Solonchaks in the arid districts, but inland on slightly higher elevations, are some soils that have become impregnated with a high content of sodium carbonate and generally are called black-alkali soils. They have acquired the morphological characteristics of Solonetz although not in so advanced a degree as some Solonetz in the United States (*22*). Most of them have been mapped as Teresa soils. Closely associated alkali-free soils have been mapped as Santa Isabel soils. Pedologically the Santa Isabel soils are chestnut-colored Planosols. The significance of alkali on the structure of Teresa silty clay is discussed by Roberts (*35*). Thorp (*41*) discusses several of the claypan profiles, including Santa Isabel silty clay loam.

Areas of solonetzlike soils have a most unusual microrelief, consisting of irregular-shaped large and small islandlike grassed areas (fig. 132) surrounded by depressions of dry barren wastes. Such areas in west-central United States are called slick spots and buffalo wallows. When the concentration of sodium carbonate becomes too concentrated for plant life, the surface soil of the barren areas becomes mellow, fluffy, and vesicular, and the soil particles are easy prey for wind and water erosion. The mellow layer in few places is more than one-half inch thick, but as soon as all or a part of it is removed more is formed at the expense of the compact layer below. The sudden tropical showers falling on extremely hot bare areas intensify the chemical activity, and sodium-alumina silicates are leached to a depth of the average penetration of the light rain. The eluviation process is assisted by the solvent action of the alkali on the humus-coated clay,

thus dispersing the colloids. The topmost inch becomes sandier and has less concentration of sodium and potash and generally a higher content of calcium than the columnar nearly impervious clay below.

Immediately after a rain the barren areas have a uniform surface color and are devoid of visible cracks, but on drying thousands of threadlike cracks develop, and streaks of brownish-black stains, probably dissolved organic matter, occur along the larger cracks. Phenolphthalein when applied to the soil in the dark-colored strips produces a strong pink color almost immediately, but when applied to the interspaces between the stained strips the pink color is less pronounced and is slow in appearing, indicating that the lighter colored part of the alkali spots contains the least sodium carbonate. The most conspicuously stain-coated areas are at the base of the one-step-high grassed areas adjacent to the barren spots. The dissolved organic matter, following the least resistance, flows from the source around the grass roots to the adjacent lower elevation. In many places it enters the cracks and may coat the cleavage plane of the columns to a depth of 12 inches.

A profile of an area of Teresa loam [28] impregnated with sodium carbonate and sodium bicarbonate, one-half kilometer, or about one-third of a mile, west of Hacienda Teresa, was studied. The climate is characterized by a mean annual precipitation of about 42 inches, and a mean annual temperature of about 78° F. The land, which is nearly level, is slightly lower than the surrounding areas. It lies at an elevation of about 10 feet above sea level. The vegetation is mainly horquetilla and junquillo, although there are many barren areas. Junquillo nearly everywhere is a sure indicator of a fairly strong concentration of sodium carbonate. The parent material consists of old alluvial fan material washed from limestone and tuffaceous hills. Drainage is poor because of the high water table and low elevation.

A description of the profile of this soil follows.

0 to one-half inch, material that is mellow when dry and when wet is soft like dough but is not plastic. It gives a strong pink color with phenolphthalein. The material in the upper part of the layer is olive-gray vesicular faintly platy sandy loam; in the middle part it is yellowish-gray slightly vesicular fine sandy loam and is more firm than the material above; and in the lower part it consists of a film of a brownish-black substance, probably dissolved organic matter, which coats the surfaces of the columns of the underlying layers to a depth of several inches.

½ to 1½ inches, light-brown calcareous softly granular plastic loam. The structural aggregates of this layer have faintly polished surfaces, and the soil breaks into more or less cubical lumps. If the overlying fluffy layer is removed from a considerable area the microrelief presents a wavy concave-convex glazed appearance. The upper boundary of this layer is sharply defined, but the lower one is indistinct.

1½ to 9 inches, brown hard calcareous prismatic heavy loam. The columns are 3 or 4 inches in diameter and 6 or 8 inches long. They have sharp edges and slightly polished surfaces. A broken prismatic column has a massive appearance. There is little change in color at the extreme of moisture content or when the soil is crushed. It is difficult for water to penetrate this layer, and even after heavy rains it remains fairly dry. When pulverized and mixed with water it becomes sticky and moderately plastic. When phenolphthalein is added to the wet material, the upper 3 inches turns pink.

[28] This profile has been previously described (*35*) as Santa Isabel silty clay. Owing to recent information the description has been changed in a few places.

9 to 15 inches, dark-brown prismatic calcareous plastic loam. The prisms are less distinct than in the layer above, but they break into more distinct fragmentary aggregates, which, in turn, can be readily crushed to fine particles. The material in this layer is in general wetter and more plastic than that in the layer above, and it contains many roots of the junquillo plant. The material in this layer is the heaviest in the profile.

15 to 30 inches, medium-plastic yellowish-brown calcareous loam, mottled with faint reddish brown in the upper part and greenish gray in the lower part. This material is easier to crush than that in the layer above, and it contains more plant roots.

30 to 48 inches, mottled gray, bluish-green, and rusty-brown friable sandy loam characterized by poorly developed soft structural units. This is the zone of greatest lime accumulation. The lime occurs in splotches, concretions, and finely disseminated form. The concretions are solid, irregular in shape, and range from one-fourth to one-half inch in diameter.

48 to 60 inches, bluish-gray loose friable coarse sandy loam. The material in this layer is moderately calcareous. The water table lies at a depth ranging from 30 to 48 inches. Owing to the hydrostatic pressure, the underground water rises 10 or 12 inches above the water table in open holes.

The character and vigor of the reaction when hydrochloric acid is applied varies considerably in the different layers of the profile. Throughout the upper 3 or 4 inches of soil, the acid quickly produces a multitude of extremely small bubbles. The effervescence has a decidedly milky appearance, probably because of the abundance of sodium carbonate. At increasing depths the bubbles gradually become larger and the milky effervescence decreases, practically disappearing at a depth of 12 inches. Below this depth and continuing to the base of the lime zone, effervescence becomes increasingly vigorous, but the bubbles are large and clear. Below the lime zone the vigor of the reaction decreases.

Table 19 shows the analysis of the water extract of this profile and a somewhat similar profile collected just 9 feet distant from a recently plowed sugarcane field where the production of cane is good. This table shows that below a depth of 15 inches there is little difference in the total salts of the two profiles, but the soil producing only grasses and sedges contains about 9 times as much salt in the first 15 inches and about 28 times as much in the upper 1½ inches as the soil producing sugarcane.

Table 19.—*Chemical analysis of water extract of two soils in Puerto Rico* [1]

TERESA LOAM

Depth (inches)	Total solids	HCO_3	CO_3	Na_2O	K_2O	SO_3	Cl	CaO	MgO
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0–½	0.590	0.103	0.042	0.283	0.120	0.106	0.010	0.020	--------
½–1½	.820	.160	.060	.294	.016	.132	.026	.012	0.007
1½–9	.300	.040	.040	.153	.013	.033	.017	.010	--------
9–15	.100	--------	.036	.053	--------	--------	.017	--------	--------
15–30	.063	--------	.022	.037	--------	.012	--------	--------	--------
30–48	.049	--------	.016	.026	--------	.009	--------	--------	--------
SANTA ISABEL LOAM COLLECTED 9 FEET FROM SAMPLE OF TERESA LOAM									
0–8	0.026	--------	0.015	0.010	--------	0.005	(2)	--------	--------
8–14	.075	--------	.026	.046	--------	.015	(2)	--------	
14–30	.093	--------	.030	.053	--------	.019	0.010	--------	--------
30–40	.091	--------	.030	.053	--------	.011	.010	--------	--------
40–56	.083	--------	.015	.041	--------	.011	.007	--------	--------

[1] Analyst, G. J. Hough, assistant chemist, Division of Soil Chemistry and Physics, Bureau of Plant Industry.
[2] Trace.

Table 20 shows the mechanical analysis of Teresa loam. The texture of the material in the several layers is about the same, but the physical characteristics differ exceedingly.

TABLE 20.—*Mechanical analysis,[1] organic-matter content, and pH value of Teresa loam*

Depth (inches)	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Organic matter [2]	pH[3]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
0–½	3.3	9.3	9.0	19.1	17.0	25.3	17.0	1.6	10.42
½–1½	3.6	8.0	8.7	19.3	16.7	22.1	21.5	1.5	10.33
1½–9	2.4	8.4	8.8	19.9	16.0	21.2	23.2	.8	9.80
9–15	2.9	7.9	8.2	18.5	15.7	21.0	25.9	.2	9.00
15–30	2.3	6.6	8.5	20.5	15.7	20.7	25.5	.1	8.90
30–40	2.3	5.7	8.0	20.2	16.3	23.0	24.5	.1	8.83

[1] Analysis by H. W. Lakin, assistant chemist, Division of Soil Chemistry and Physics, Bureau of Plant Industry.
[2] Organic matter by H_2O_2 and mineral matter dissolved by H_2O_2.
[3] pH determinations made by the hydrogen-electrode method by E. H. Bailey, assistant soil technologist, Division of Soil Survey, Bureau of Plant Industry.

Nearly all alkali areas having a concentration exceeding 0.4 percent of sodium carbonate in the surface soil have similar morphology, especially in the upper few inches. If the soil is plowed, the upper layers are mixed with the heavier textured underlying layers, and the soil becomes a sticky puddled mass when wet and forms hard dense clods when dry; but if returned to pasture for several years, the gray fluffy thin surface layers are developed again.

Nearly all areas affected with sodium carbonate occur within districts receiving less than 40 inches of mean annual rainfall, although a few slightly affected areas occur in places where the rainfall is about 50 inches.

The normal profile of this section is classified with the Reddish Chestnut soil group. It differs from that of the previously described Teresa loam in that it has a brown or chestnut-brown granular alkaline surface soil about 8 or 10 inches thick, underlain by a light-brown (with a red tint in places) generally heavy plastic alkaline layer 10 or 12 inches thick, which, in turn, is underlain by a lime zone of yellowish-brown fairly friable material. The lower layers are friable and in general lighter in texture than the B horizon.

The depth of the lime zone depends on the penetration of soil moisture, and this, in turn, depends on soil texture, relief, and precipitation. Other factors being equal, the sandier the soil texture and the greater the precipitation, the deeper is the lime zone. Depressions have a deeper lime zone, owing to more soil moisture, than do level areas, and they, in turn, have deeper lime zones than do undulating or rolling areas. Soils having a compact nearly impervious B horizon may have a relatively shallow lime zone, because the lime is protected from percolating waters.

The same factors affecting the depth of the lime zone also affect the leaching of other bases. Plants, especially grasses, bring bases from the lower soil layers through their deep roots, and deposit it on the surface through the decomposition of the fallen leaves. Thus, even if the surface soil is leached, it is continually being replenished with bases so long as the lime is within reach of any of the plant's roots, therefore the surface horizons tend to remain neutral and

the colloids remain saturated with calcium and are comparatively immobile.

Some of the most important Reddish Chestnut soils are types of the Paso Seco, Fé, and Fraternidad series. There is such a gradual change between the soils of this group and the Chernozems that some areas of each soil could be classified also with the Chernozems.

Table 21 shows the base exchange of the heaviest layer of three Reddish Chestnut soils.[29] The exchangeable bases are high, as may be expected from soils of this group. All these soils are highly productive when properly managed and irrigated. The cultivated areas are occupied exclusively by sugarcane, which is generally high in sucrose.

TABLE 21.—*Exchangeable bases in heaviest layer of three Chestnut soils in Puerto Rico* [1]

(Calculated as milliequivalents per 100 grams)

Soil type	Soil survey No.	Laboratory No.	Depth	CaO	MgO	K_2O	Na_2O	Total
			Inches					
Santa Isabel silty clay	580526	8108	6–12	33.6	3.2	0.19	2.5	39.49
Paso Seco loam	580570	8109	16–28	24.3	3.7	.21	.5	28.71
Fé clay	580558	8110	10–22	34.6	3.7	.34	.7	39.34

[1] Analyst, G. Edgington, assistant chemist, Division of Soil Chemistry and Physics, Bureau of Plant Industry.

THE 35- TO 45-INCH RAINFALL BELT

Topographically, the 35- to 45-inch rainfall belt is similar to the previously described district dominated by the Reddish Chestnut soils. This belt is much larger, but instead of extensive areas of playa plains, numerous level or undulating inner plains are nestled between high steep grass-covered hills, which dominate this district and are almost exclusively occupied by large cattle ranches.

Geologically, this area includes Tertiary and Cretaceous limestone, shale, tuff, serpentine, rhyolite, conglomerates, sandstone, and granite. Calcification is the most important but not the only soil-developing process at work within this area. Laterization, podzolization, and both salinization and solonization may be observed in parts of the area where the combination of environmental conditions is favorable for the development of these processes.

One of the most important factors that influences the soil-developing process of these shallow soils on steep hillsides is the composition of the parent rock. Other factors being equal, if the parent rock is exceedingly low in soluble bases, such as calcium and magnesium, and is high in aluminum, the soil produced will be low in bases, gray, slightly plastic, and acid. If the parent rock is only medium low in soluble bases and high in iron, the soil produced, even in the arid districts, will be red or reddish brown and neutral in reaction. If the parent rock is high in soluble bases and medium low in iron and aluminum, the soil produced will be alkaline. If the parent rock is exceedingly resistant to weathering, such as some of the limestone previously discussed, the soil will be lateritic, even though it is derived from rocks high in soluble bases.

[29] Although Santa Isabel silty clay has been classed with the Planosols, it bears a close pedological relationship to the Reddish Chestnut soils.

The Mariana, Guayama, and Descalabrado soils are representative respectively of the podzolization, laterization, and calcification soil-forming processes. These three soils are developed on similar relief, have about the same climatic conditions, and support somewhat similar vegetation, but each is derived from parent rock decidedly different in composition. All three soils are relatively immature. The Mariana soils are characterized by a 4- or 6-inch light grayish-brown nearly structureless acid silt loam surface soil, underlain by a nearly white floury acidic layer that is plastic when wet. This grades into the disintegrating siliceous rhyolite parent rock at a depth of 8 or 10 inches. The parent rock is noncalcareous and dense. This soil is used extensively for the production of pineapples and less extensively for grass and minor truck crops. The Guayama soils are characterized by a 4- or 6-inch reddish-brown fairly granular heavy-textured permeable neutral surface soil, underlain by permeable red or reddish-brown neutral clay, which grades into partly disintegrated green augite andesites and medium-plastic brown or reddish-brown material at a depth of about 15 inches. The parent rock is calcareous at low depths. This soil is somewhat similar to the Terra Rossa as well as to the lateritic soils of the humid districts. It has a higher content of bases and produces more nutritious grass than do the lateritic soils of the humid districts. This soil is used mostly for range pasture. The Descalabrado soils are characterized by a brown or chestnut-brown granular medium-plastic alkaline clay or silty clay layer that is underlain by yellowish-brown alkaline and slightly granular clay, which grades into partly disintegrated tuffaceous rock and light yellowish-brown plastic silty material at a depth of about 12 inches. This soil is used extensively for grass, which is said to be very nutritious.

The tuffaceous and siliceous igneous rocks also occur in areas having a high annual rainfall. As has been previously stated, the soils produced from the tuffaceous rocks are influenced by the quantity of soil moisture received, and they may represent any one of the important zonal groups, depending on the precipitation. The siliceous rocks, however, apparently are influenced more by podzolization than by any other process, regardless of the soil moisture.

The granitic rocks, especially quartz diorite, occupy a considerable area in Isla de Vieques in the 35- to 45-inch rainfall belt, as well as large areas in eastern Puerto Rico where the annual rainfall exceeds 80 inches. Two very dissimilar soils are produced in these areas. In Isla de Vieques, on the hills, the 6- or 8-inch surface soil is dark grayish-brown or very dark grayish-brown neutral faintly granular friable fairly heavy loam. It is underlain by a brownish-red neutral friable permeable B horizon that is heavier than the A horizon. The C horizon consists of coarse-grained gray alkaline partly disintegrated granite, which grades into hard granite of the quartz diorite variety at a depth of about 30 inches. This soil is Vieques loam. In areas of high rainfall, soil from similar parent rock is mapped as Pandura sandy clay loam, which is characterized by a grayish-brown friable excessively drained strongly acid sandy clay loam surface soil, about 6 inches thick. This is underlain by very light grayish-brown single-grained strongly acid sandy loam, which grades into disintegrated quartz diorite at a depth of 20 inches, and this material, in turn, grades into the parent rock at a depth ranging from about 40 to 50 inches.

FIGURE 137.—See legend on page 443

It may readily be seen that the Pandura soils have been influenced by podzolization and that the Vieques soils have developed under the influence of both calcification and mild laterization. They are closely related to the soils classified as Reddish Prairie. Associated mature soils on undulating relief indicate the same trend of soil development but in a more advanced stage. In Isla de Vieques, the Llave soils, developed on old terrace positions from material washed from the granitic hills, show more reddish development than the Vieques soils. The Humacao soils have developed in terrace positions from material washed from the Pandura and other soils of granitic origin, and they belong to the Gray-Brown Podzolic soils group.

Serpentine, the rock that readily develops into a ferruginous laterite in humid areas on favorable relief, occurs in this semiarid district, but the soil produced has little or no physical evidence of laterization. It has a brown alkaline granular silty surface soil about 6 inches thick, underlain by a shallow slightly heavier light-brown alkaline B horizon, which grades slowly into the smooth talclike serpentine rock at a depth of 12 or 14 inches. Areas favorably situated to receive a much higher content of soil moisture than is common to this rainfall belt show a distinct red color, indicating a tendency toward laterization.

An interesting feature of this rainfall belt, as well as of certain areas in the 45- to 60-inch rainfall belt, is the formation of a strongly indurated or cemented layer near the surface in rolling areas and at the surface in steep eroded areas. The hardpan occurs only in soils derived from parent rock that is very low in soluble bases. The soil developed is strongly acid, and apparently iron hydroxide in finely divided colloidal suspension is leached to a greater depth, where most of it is precipitated around rock fragments. It coagulates and forms a mass resembling conglomerates. Undoubtedly the effect of an intermittently dry hot climate is responsible, mainly, for the hardpan formation, as it does not occur in moist districts. Iron concretions and bog iron, however, are conspicuous in the humid areas. Owing to its small extent, positive statements regarding the hardpan formation cannot be made. It was observed near Fajardo on Yunes silt loam, near Lajas on Mariana clay loam, and near Faro Cabo Rojo on Cabo Rojo clay.

The salinization and solonization processes, by which the Solonchak and Solonetz are formed, take place along the playa plains in the eastern part of this belt. They have been much less influential than in the 25- to 35-inch rainfall belt.

Calcification is the dominant soil-forming process on the undulating areas in this district, which have deep well-drained mature soils. This process of development has been dominant in the formation of the Red Desert soils, Reddish Brown soils, Reddish Chestnut soils, and Chernozems. In brief, it consists of the formation of calcium carbonate through the carbonation of calcium generally brought to the surface by plants and its leaching to lower depths, where it is precipitated generally in the forms of concretions and splotches (fig. 137). The

FIGURE 137.—Soil profile of Coamo clay. Note the cracks from the surface to the zone of maximum lime carbonate.

Perfil del Coamo arcilloso. Nótese las grietas desde la superficie hasta la zona de máxima concentración de carbonato calizo.

depth of deposition corresponds to the mean annual depth of percolation of the surface water. In the Chernozem soils the depth to the zone of maximum lime accumulation is greater than in the Reddish Chestnut soils and much greater than in the Reddish Brown soils. The calcification process is best maintained in a section favorable to grass vegetation and in areas of restricted soil moisture.

Ponceña clay, which is well distributed throughout the inner plains of the 45- to 55-inch rainfall belt, has characteristics much in common with a Chernozem and has developed under the process of calcification. A profile of this soil was examined 1 mile northwest of Coto Laurel, in a level or slightly undulating area where external drainage is good and the internal drainage ranges from fair to good. The vegetation consists of a dense growth of guinea grass and horquetilla. The parent material is limy shale. The climate is characterized by a mean annual rainfall of about 45 inches and a mean annual temperature of about 76° F.

The results of this examination follow.

0 to 7 inches, very dark grayish-brown or black granular alkaline clay, which is waxy and plastic when wet and dense and hard when dry. The granules are rounded, medium hard, and distinct, and there are many worm and insect borings and casts. The granules become more angular and slightly more dense and fragmentary with depth toward the lime zone. The soil mass swells and contracts greatly at extremes of moisture content.

7 to 15 inches, yellowish-brown medium plastic alkaline clay with fragmentary polished structural units that fit together like plant cells. Some of the nearly black particles from the layer above have filtered down root channels and cracks, and some have been deposited by worms and microorganisms. This material is hard when dry and plastic when wet.

15 to 23 inches, light yellowish-brown very heavy and tough plastic alkaline clay. The material in this layer is the heaviest and most dense in the profile. When wet it sticks tenaciously to the soil auger or spade when withdrawn after penetrating the horizon. At the extremes in moisture content, the material in this layer swells and contracts more than that in any other layer.

23 to 27 inches, a transitional zone to the calcium carbonate accumulation. It consists of grayish-yellow medium friable faintly granular silty clay. Lime occurs in disseminated form.

27 to 50 inches, the zone of calcium carbonate accumulation. It consists of mottled olive and yellowish-brown cloddy friable silty clay loam. The irregular clods are perforated with pen-point-sized holes, and they crush readily to a mellow friable mass. Calcium carbonate, which is very abundant, occurs as rounded concretions, splotches, in disseminated form, and as coatings around soil particles. The concretions range from ¼ to 1 inch in diameter. Their outer coatings generally are soft and white and their centers dull and solid.

50 inches+, olive calcareous silty clay loam that contains much less visible calcium carbonate than the material in the layer above.

The porosity and aggregation of this profile is discussed by Baver, Engle, Roberts, and Templin (7). Their data show that there is a high state of aggregation and porosity in all layers, but especially in the surface soil, and this is probably the reason for the good granular structure of that horizon.

Other soils that are closely associated and have similar morphology and genesis are the Coamo, the Portugués, and the Río Cañas, also the Camagüey and Santa Clara soils of the more humid districts, which are derived from soft limestone rock.

Table 22 shows the mechanical analyses of samples of Santa Clara clay, collected near Aguada, where the mean annual rainfall is ap-

proximately 75 inches. The mechanical analysis of Ponceña clay would probably be very similar. The analysis of Santa Clara clay shows that there has been considerable translocation of clay, especially colloidal clay, from the A to the B horizon. It shows that the proportion of colloidal clay to total clay is high in the A and B_1 horizons but low in the B_2 and very low in the C horizon. The silt content of the C horizon is very high, indicating that the limestone probably is a limy shale or one in which considerable silt was deposited during sedimentation.

TABLE 22.—*Mechanical analysis of Santa Clara clay* [1]

Sample No.	Horizon	Depth	Fine gravel (2-1 mm.)	Coarse sand (1-0.5 mm.)	Medium sand (0.5-0.25 mm.)	Fine sand (0.25-0.1 mm.)	Very fine sand (0.1-0.05 mm.)	Silt (0.05 0.005 mm.)	Clay (0.005-0 mm.)	Colloid (0.002-0 m.)	Organic matter [2]
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5804142	A	0–5	0.6	1.6	1.2	3.6	13.2	33.9	45.9	41.9	5.2
5804143	B_1	5–17	.2	.7	.7	2.6	8.8	32.8	54.1	50.6	3.3
5804144	B_2	17–24	.1	.2	.3	1.1	5.5	42.9	49.8	37.1	.6
5804145	C	24–50	1.1	2.3	1.5	1.8	3.8	58.9	30.5	16.6	.4

[1] Analyst, H. W. Lakin.
[2] Analysis based on organic-free oven-dry sample. Organic matter by H_2O_2. Mineral matter dissolved by H_2O_2 was about 3 times the amount of organic matter for the B_2 and C horizons.

Table 23 shows the base exchange of the A and B horizons of Santa Clara clay, of the B horizon of Ponceña clay, and of some of the parent rock from the Santa Clara soil. As could be expected, the analyses show a relatively high total base-exchange capacity.

TABLE 23.—*Exchangeable bases in Chernozem soils*

(Calculated as milliequivalents per 100 grams)

Soil type	Soil survey No.	Laboratory No.	Depth	CaO	MgO	K_2O	Na_2O	Total
			Inches					
Santa Clara clay [1]	5804142	10040	0–5	30.8	1.5	0.19	1.0	33.49
Santa Clara clay [1]	5804143	10049	5 17	29.2	2.5	.23	1.1	33.03
Santa Clara clay [1]	5804148	10051	(2)	67.1	.3	.12	.7	68.22
Ponceña clay [3]	580558	8110	12–16	47.2	2.7	.28	.6	50.78

[1] Analyst, G. J. Hough. N/20 HCl method used.
[2] Parent rock.
[3] Analyst, G. Edgington. N NH_4Cl method used.

THE 45- TO 60-INCH RAINFALL BELT

The 45- to 60-inch rainfall belt includes not only a long ribbonlike area of rolling, steep, and very steep hills with sloping intervening inner valleys south of the Cordillera Central and along the eastern and western tips of the island but also a part of the northwestern coastal plain near Isabela.

Owing to differences in parent rocks, the morphological characteristics of the northwestern coastal plain are distinctly different from those of the southern, eastern, and western districts.

Laterization is the predominating soil-forming process near Isabela, and Coto clay is one of the normally developed soils. Calcification

and podzolization are the principal soil-forming processes in the other areas, and soils resembling the Reddish Prairie soils are developed.

The Coto soils are developed typically on nearly level or undulating coastal plains where the mean annual rainfall ranges from 45 to 60 inches. They have been derived from Tertiary limestone and have developed into lateritic soil. The Coto and associated soils, such as the Espinosa, Maleza, Bayamón, Matanzas, and others, are well drained, permeable, and therefore well oxidized, and they are red or yellow. They possess a number of characteristics typical of the lateritic soils. They have similar physical and chemical characteristics from the surface to the underlying limestone. They have a high percentage of clay-sized particles which are more or less grouped in aggregates. The capillary pores are not clogged, owing to the small extent of swelling of the wet particles, therefore water and air penetrate rapidly. Under these conditions run-off is slight, but the soil dries quickly and deeply. A clod readily slakes to small crumblike particles after one or two tropical showers.

Following is a description of a typical profile of Coto clay taken one-half kilometer north of Kilometer 132, which is 9¼ kilometers directly east-northeast of Aguadilla, on Carretera No. 2, in an area that has been cultivated. The land is nearly level. The parent material is Quebradillas limestone. The climate is characterized by a mean annual rainfall of 52 inches and a mean annual temperature of 78° F.

0 to 7 inches, yellowish-brown or reddish-brown faintly granular friable permeable slightly acid clay with the structural characteristics of a loam. Numerous conspicuous sand grains are present in this layer, which is much darker than the lower layers, probably because of a higher content of organic matter. The water-holding capacity seems to be highest in this layer.

7 to 17 inches, reddish-brown slightly compact and slightly plastic but permeable clay. The material is slightly acid.

17 to 40 inches, yellowish-brown massive medium friable permeable clay. The clods are perforated. The material is slightly acid.

40 to 70 inches, very similar to layer above, except that many red splotches one-half inch in diameter occur along cracks and seams, indicating that this layer is slightly more resistant to the penetration of water than the layers above. The material is slightly acid.

Limestone occurs at a depth ranging from 4 to 10 feet.

One of the most striking features of the mechanical analysis, as shown in table 24, is the small quantity of silt and sand and the exceedingly high content of colloidal clay in all horizons. This indicates that the eroded material that was mixed with the limestone during the sedimentation was mostly of a clay-sized fraction. The sand grains in the surface layer probably have been blown in by the wind. Areas nearer to the sea have a larger percentage of sand grains in the upper layers. The organic-matter content is high in the A_1 horizon, which accounts for the dark surface soil. The data indicate that there has been some translocation of clay from the A_1 to the B horizon but not a large amount in comparison with the content of clay in each horizon. The analyses indicate that all the soil layers should be fairly similar in physical characteristics, but there is nothing to indicate that they are extremely permeable.

TABLE 24.—*Mechanical analysis of Coto clay* [1]

Sample No.	Horizon	Depth	Fine gravel (2–1 mm.)	Coarse sand (1–0.5 mm.)	Medium sand (0.5–0.25 mm.)	Fine sand (0.25–0.1 mm.)	Very fine sand (0.1–0.05 mm.)	Silt (0.05–0.005 mm.)	Clay (0.005–0 mm.)	Colloid (0.002–0 mm.)	Organic matter by H_2O_2
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
5804130	A_1	0–7	0.1	3.1	5.1	9.7	8.1	6.5	67.4	66.2	5.2
5804131	B_1	7–17	.1	2.0	3.4	7.3	5.8	3.2	78.2	77.3	2.5
5804132	B_2	17–40	.2	1.1	1.8	3.4	3.6	2.0	88.0	87.5	.9
5804133	C	40–70	.1	1.2	1.7	2.8	3.6	4.2	86.4	84.8	.8

[1] Analyst, H. W. Lakin.

The chemical analysis of the whole soil is shown in table 25. These data show that silica decreases and iron and alumina increase with depth. A critical deficit exists in bases, especially potassium and magnesium. Crops also indicate a lack of available plant nutrients, as yields are never very high.

TABLE 25.—*Chemical analysis of Coto clay* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
5804130	A_1	0–7	47.52	14.39	21.53	0.36	0.23	0.18	0.05	1.15	0.31	0.36	0.20	13.90	100.18	4.90	0	0.31
5804131	B_1	7–17	45.24	15.97	24.48	.38	.18	.15	.03	1.17	.21	.33	.16	12.25	100.55	2.02	0	.16
5804132	B_2	17–40	38.36	18.65	27.91	.33	.24	.23	(2)	1.17	.12	.44	.14	12.57	100.16	.88	0	.12
5804133	C	40–70	38.26	19.37	27.58	.34	.12	.19	.04	1.22	.11	.45	.13	12.33	100.14	.79	0	.10

[1] Analyst, G. Edgington. [2] Trace.

The silica content in the colloid analysis table 26 indicates that the sands in the A and B_1 horizons must be mostly quartz. Owing to the high content of colloidal clay in this profile, very little difference could be expected between the chemical analysis of the colloid and that of the complete soil. The data bear this out.

TABLE 26.—*Chemical analysis of Coto clay colloid* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
5804130	A_1	0–7	30.55	18.17	31.09	0.50	0.12	0.27	0.06	1.07	0.12	0.53	0.20	17.53	100.21	2.34	0	0.33
5804131	B_1	7–17	30.89	21.46	29.89	.46	.23	.17	.03	1.22	.11	.50	.15	15.19	100.30	1.55	0	.22
5804132	B_2	17–40	31.18	18.13	33.66	.38	.16	.27	.05	1.03	.07	.54	.10	14.56	100.13	1.24	0	.19
5804133	C	40–70	31.03	20.27	31.62	.39	.29	.39	.02	1.17	.08	.54	.11	14.61	100.52	1.50	0	.19

[1] Analyst, G. Edgington.

Table 27 shows the derived data of this lateritic soil. The silica-sesquioxide ratio is low but not so low as that of a true Laterite or one that is impoverished of nearly all bases. This soil appears to be more laterized than the Cecil or Davidson soils of continental United States but much less so than the Nipe sóil that occurs from 15 to 20 miles south of this soil.

TABLE 27.—*Derived data: Coto clay*

Sample No.	Horizon	Depth	Molecular ratio $\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	Water of hydration
		Inches						*Percent*
5804130	A_1	0- 7	1.21	4.46	1.67	0.374	27.6	15.19
5804131	B_1	7 17	1.20	3.82	1.75	.387	28.9	13.64
5804132	B_2	17-40	1.17	4.89	1.57	.337	32.5	13.32
5804133	C	40-70	1.18	4.21	1.67	.408	70.3	13.11

Table 28 shows the total and exchangeable bases in the A and B horizons of Coto clay. The data show that the bases are exceedingly low, although a large percentage is exchangeable.

TABLE 28.—*Comparison of total and exchangeable bases in Coto clay*

(Calculated as milliequivalents per 100 grams. Base exchange N/20 HCl)

Sample No.	Horizon	Depth	CaO Total	CaO Exchangeable	MgO Total	MgO Exchangeable	K_2O Total	K_2O Exchangeable	Na_2O Total	Na_2O Exchangeable
		Inches								
5804130	A	0- 7	8.2	5.7	18	1.5	3.8	0.32	1.5	0.84
5804131	B	7-17	6.4	.8	19	.8	4.05	.15	.9	.87

Table 29 shows the mechanical analysis of Matanzas clay, a soil very similar in position to Coto clay and derived from similar parent rocks and presumably under similar vegetation. The two samples were collected within 2 miles of each other, the Matanzas clay area to the southwest. The Matanzas soils are red or reddish purple from the surface to the underlying limestone. The soils of both series have nearly identical physical characteristics. If there is any difference in permeability it is in favor of the Matanzas soils, which are considerably more productive. The pH value is higher in the Matanzas soils. The mechanical analysis of Matanzas clay shows that the clay content is exceedingly high, especially in the A and B horizons. The soil, however, has the physical characteristics of a loam or sandy loam, and it can be cultivated within a half hour after a 1- or 2-inch rain without harming its structure.

TABLE 29.—*Mechanical analysis of Matanzas clay* [1]

Sample No.	Horizon	Depth	Fine gravel (2-1 mm.)	Coarse sand (1-0.5 mm.)	Medium sand (0.5-0.25 mm.)	Fine sand (0.25-0.1 mm.)	Very fine sand (0.1-0.05 mm.)	Silt (0.05-0.005 mm.)	Clay (0.005-0 mm.)	Colloid (0.002-0 mm.)	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
580401	A	0-12	0.1	0.4	0.8	2.4	2.7	2.1	91.4	90.6	2.1
580402	B_1	12-21	.1	.4	.4	1.9	2.0	2.4	92.9	92.4	.8
580403	B_2	21-34	.1	.3	.6	1.9	2.3	11.8	83.1	80.1	.1
580404	C_1	34-68	0	.2	.5	2.2	3.6	16.3	77.2	72.2	0
580405	C_2	68+	.1	.2	.3	1.6	3.9	20.5	73.5	68.6	0

[1] Analyst, H. W. Lakin.

Table 30 shows the chemical analysis of Matanzas clay. It may be seen that bases and ignition loss are slightly higher in this soil than in Coto clay, indicating that the vegetation and crops should be slightly better on the Matanzas soils than on the Coto soils, and this agrees with field observations.

TABLE 30.—*Chemical analysis of Matanzas clay* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
580401	A_1	0–12	37.20	17.34	28.79	0.52	0.25	0.23	0.02	1.09	0.14	0.27	0.16	15.03	101.04	0	0.20
580402	B_1	12–21	36.46	19.46	29.21	.44	.18	.16	.05	.85	.11	.26	.19	13.45	100.82	0	.13
580403	B_2	21–34	36.24	18.48	30.84	.41	.23	.23	.12	.85	.11	.22	.15	12.88	100.76	0	.09
580404	C_1	34–68	35.98	19.20	30.76	.51	.10	.21	.10	.85	.06	.22	.11	12.28	100.38	0	.09
580405	C_2	68+	35.25	19.73	30.91	.46	.18	.21	.10	.85	.05	.24	.11	12.51	100.60	0	.09

[1] Analyst, G. J. Hough.

The chemical as well as the mechanical analyses of the two soils are so nearly identical that positive differentiating statements cannot be made. The Matanzas soils generally, but not always, occur nearer to the limestone hills than do the Coto soils. That is to say, in circling the limestone haystack hills one is more likely to find Matanzas clay than Coto clay. The wash from the limestone in the semiarid district may be sufficient to keep the Matanzas soils more alkaline, therefore more productive.

It is also possible that the Matanzas soils are slightly younger, and this may account for their red color. The Bayamón soils, which occur in more humid districts to the east, however, are equally as red as the Matanzas and undoubtedly as old as the Coto soils. They are much more acid than either the Coto or the Matanzas soils. It would appear that neither the age nor the pH value is the principal cause for the difference in color. The vegetation apparently has not had much influence on the morphological characteristics, as similar vegetation occurs on all areas. The permeability of some of the soils may be sufficiently different to make for better oxidation, therefore the Bayamón and Matanzas soils are red, and the Espinosa and Coto soils are yellow.

Table 33 gives the mechanical analysis of Bayamón fine sandy loam. The silt content is exceedingly low, and nearly all of the clay is colloid. This sample was collected one-fourth mile north of Estación Martín Peña.

TABLE 31.—*Mechanical analysis of Bayamón fine sandy loam* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802134	A	0–10	0.1	4.0	30.7	52.2	5.4	2.8	4.7	4.6	1.1
5802135	B	10–24	0	3.2	28.4	48.7	5.5	1.9	12.3	12.3	.1
5802136	C	24–40	0	2.4	25.6	43.4	4.7	1.7	22.1	20.8	.1

[1] Analyst, H. W. Lakin.

Table 32 gives the mechanical analysis of a sample of Bayamón clay collected about 4 miles southwest of Dorado in a virgin forest. These data are similar to the mechanical analyses of the Matanzas and Coto soils, but the organic content is higher, owing to the virgin conditions.

TABLE 32.—*Mechanical analysis of Bayamón clay* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802116	A	0–8	0.1	0.9	2.9	2.9	1.2	2.8	89.2	87.7	5.4
5802115	B	8–30	0	1.0	2.2	2.0	.4	.8	93.7	93.3	1.4
5802117	C	30–40	0	.7	1.8	1.7	.4	.2	95.1	94.3	1.0

[1] Analyst, H. W. Lakin.

Probably the most striking features of the landscape in the Prairie soils part of this rainfall belt are the numerous houses, eroded hillsides, and intricate mosaic of irregular-shaped gardens of the jibaros. The pressure of the ever-increasing population forces the cultivation of hills so steep that only hand tools can be used. In the areas receiving less than 40 inches of mean annual rainfall the farmers seldom cultivate the hillsides, as they know they will not reap a harvest, but in the 45- to 60-inch belt there is enough rainfall to tempt them to plant crops on the hillsides. Unfortunately the only crops they plant are the clean-cultivated ones, such as beans, corn, pigeonpeas, and tobacco. The rainfall is sufficient for these crops to grow, but it is not sufficient for the rapid growth of these plants or grasses. Therefore, during intense rains the soil erodes, as there is not sufficient vegetation to retard the flow of water. When the land becomes so unproductive that it is abandoned, small gullies appear before the slow-growing pasture grasses can become sufficiently well established to reduce the force of the dashing rains. These eroded areas are very conspicuous.

Many of the hill slopes that terminate in the flood plains are gentle, but they are so long that run-off following a heavy rain at the end of the dry season causes considerable erosion of the gully type leading to the narrow barren arroyos. In the humid districts all such drainageways are grassed over, thereby preventing gully erosion.

In the areas where the mean annual rainfall is in excess of 60 inches, vegetation grows so quickly and densely that the force of the running water is checked and does very little damage. Under a heavy growth of vegetation the soil granules are bound together by countless plant roots. In addition, most of the soils in the humid area are derived from tuffs and shales that contain a very small amount of quartz. When these rocks weather, a soil is developed that is high in permeable clay, medium low in silt, and very low in sand. The soils are without a high content of silt that may melt away like sugar under a tropical shower; or, because of the abrasive effect of soil material washing down the hillsides, erosion in many places only keeps pace with the rapid decomposition and disintegration of the rocks. The moist hot climate is ideal for the rapid growth of plants as well as for the fast decomposition of vegetation, which adds carbon dioxides to

the soil water, making it acidic and thus increasing its solvent action. Under these conditions and with a high biological pressure, rocks weather rapidly and decomposition keeps pace with normal erosion. Another reason that erosion is less severe is because the run-off in the humid district has a steep but short course before it empties into grass-covered healed-over ravines or rock-bottomed small streams.

There has been more geologic erosion along the humid northern coast than along the arid southern coast, as indicated by the crest of the Cordillera Central, which is within a few miles of the southern coast. The crest of this range has been pushed gradually southward, owing to greater precipitation on the northern slopes, due to the direction of the trade winds and to the mountain barriers.

The best Reddish Prairie soils are developed on tuffaceous rocks where the rainfall is sufficient to support a dense grass cover on virgin sod, yet not sufficient to leach all the calcium carbonates beyond the reach of the grass roots. Daguao clay probably is one of the best examples of Reddish Prairie soils in Puerto Rico.

A profile of this soil was examined at Kilometer 2.6, Ensenada Honda road, southeast of Ceiba, in an area characterized by rolling hills, with slopes ranging from 15 to 40 percent, and at an elevation of about 100 feet above sea level. The mean annual rainfall is about 55 inches and the mean annual temperature about 75° F. The vegetation is mostly cerrillo, horquetilla, and cortadera. Drainage, both internal and external, is excellent. The parent rock is tuff.

0 to 11 inches, nearly black clay, which is waxy and plastic when wet. It is very dark grayish brown, granular, and fairly dense when dry.

11 to 18 inches, reddish-brown, mottled with dark gray, fragmentary alkaline clay. The material in this layer contains many gray specks of only slightly weathered rock, as well as some dark-colored material that has filtered down the cracks from the layer above.

18 to 35 inches, mottled brown and dark-gray plastic sticky clay. The clods break into sharp angular fragmentary particles.

35 to 42 inches +, mottled yellowish-brown and gray friable clay, grading into partly disintegrated black rock.

This soil is used mostly for pasture. Sugarcane will produce from 30 to 35 tons to the acre during excessively wet years, but in dry years the cane often dries.

THE 60- TO 75-INCH RAINFALL BELT

The 60- to 75-inch rainfall belt includes an almost continuous narrow ribbonlike area circling the island. Physiographically it includes the broad coastal and playa plains along the northern, eastern, and a part of the western coast, as well as steep rugged hills on either side of the divide of the Cordillera Central.

Geologically this rather extensive area includes some of each important rock occurring in the island.

The vegetation is dominantly mesophytic, except where the combination of excessively drained soils and steep slopes tend to make an arid soil climate and xerophytic plants predominate. This edaphic relationship of the vegetation is very conspicuous on the Rosario soils, which are shallow, very permeable, and derived from serpentine. They occupy slopes ranging from 60 to 180 percent gradient.

Podzolization is the most important soil-forming process of this area, although, in places where the soils have developed from hard or

medium-hard Tertiary limestone, laterization masks all the other soil-developing processes.

The rainfall of this area is fairly high, but it is intermittent; that is, periods of wet weather are followed by long dry periods. Soil development has many interruptions. During the rainy periods vegetation grows rapidly, decomposition is rapid, organic acids are plentiful, hydrolysis is active, and, therefore, bases and colloids are moved downward rather freely. During the dry seasons vegetational growth is retarded, evaporation from the soil is greatly increased, water movement in the soil is reversed, and some of the bases may be brought nearer to the surface. Under these conditions leaching is less pronounced than under a continuously moist climate. Leaching in this area, especially in the immature soils of the hillsides, is very sensitive to soil moisture, which, in turn, is extremely sensitive to relief. Only a small percentage of the rainfall penetrates the soils on the steep slopes; therefore leaching is less active than on the more level land. The surface soils on very steep hills are dark colored, suggest calcification, and are typical of soils developed under more arid conditions of soil climate. The soils on gentle slopes are grayish brown, acid, and leached, indicating podzolization. The well-drained soils on the level areas and areas receiving considerable water from adjacent land are reddish brown or red, signifying some laterization.

The morphology of several of the upland soils is so intricately associated with the relief that the landscape in the mountainous areas resembles a heterogeneous colored picture mosaic.

The upland soils that are closely associated are those of four series—the Múcara, Sabana, Naranjito, and Cialitos. The Múcara soils have dark-colored neutral or slightly acid surface soils and brown neutral or slightly alkaline subsoils. They are shallow, in few places being more than 16 inches thick over the partly disintegrated tuffaceous parent rock. Where the annual rainfall ranges from 55 to 65 inches the Múcara soils occupy slopes exceeding 15 percent, in rainfall areas of 65 to 75 inches they occupy slopes exceeding 40 percent, and in areas receiving more than 75 inches they occur only on slopes steeper than 60 percent.

Table 33 shows the mechanical analysis of Mabí clay, a soil very similar and closely associated with the Múcara soils, except that it is deeper and occupies long, gentle slopes. It is derived from similar parent rock and has similar physical characteristics, but it is slightly more heavy and therefore more plastic.

TABLE 33.—*Mechanical analysis of Mabí clay* [1]

(Sample collected at Kilometer 167.1, south of Rincón)

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5804156	A	0- 6	1.4	3.1	2.7	6.3	7.8	34.1	44.5	32.0	1.2
5804157	B	6-16	1.2	3.3	3.0	7.5	8.2	34.6	42.1	31.3	.9

[1] Analyst, H. W. Lakin.

Table 34 compares the base exchange of Mabí clay with that of Coloso clay, an alluvial soil derived from soil material washed from tuffaceous hills.

TABLE 34.—*Exchangeable bases of Mabí clay, a residual soil from tuffaceous rocks, and of Coloso clay, an alluvial soil derived from soil washed from tuffaceous hills* [1]

(Calculated as milliequivalents per 100 grams)

Soil type	Soil survey No.	Laboratory No.	Depth	CaO	MgO	K_2O	Na_2O	Total
			Inches					
Mabí clay	5804156	10041	0–6	24.3	5.5	0.29	1.4	31.49
	5804157	10050	6–16	19.6	10.5	.28	1.8	32.18
Coloso clay	5804149	10052	0–12	25.3	5.3	.32	1.0	31.92
	5804150	10053	12–30	20.7	4.8	.21	1.1	26.81

[1] Analyst, G. J. Hough. The N/20 HCl method of analysis was used.

The Sabana soils differ from the Múcara soils in that they are lighter colored and more acid and have a more plastic B horizon, indicating greater soil development, especially podzolization. These soils are developed under a higher soil-moisture content than the Múcara soils, as they generally occupy the heads of drainageways and the gentle slopes in the 55- to 65-inch rainfall areas, and, as the mean annual rainfall increases, the soil is developed on steeper and steeper slopes.

Table 35 shows the mechanical analysis of a sample of Sabana silty clay loam. Very close correlations exist between this analysis and the analysis of Mabí clay. The pH value of this sample, as shown in table 36, is much lower.

TABLE 35.—*Mechanical analysis of Sabana silty clay loam* [1]

(Sample collected 4 miles south of Río Piedras)

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802125	A	0–5	3.6	7.9	5.2	6.9	5.9	23.6	46.8	36.1	3.8
5802126	B	5–24	4.2	8.1	5.5	8.6	6.8	24.5	42.3	31.6	.0
5802127	C	24–40	8.7	14.3	8.1	10.3	8.0	22.2	28.3	21.3	.4

[1] Analyst, H. W. Lakin.

The Naranjito soils differ from the Sabana soils in that they have some red coloration in the subsoil and are reddish brown in the surface soil. They have about the same pH value and are about as well developed. Both podzolization and laterization are rather active in these soils, which occur in a more moist soil climate than the Sabana soils and therefore occupy considerable areas where the mean annual rainfall is between 75 and 80 inches.

Table 36 gives the pH value of a number of important soils in Puerto Rico.

TABLE 36.—*pH determinations of some of the more important soils in Puerto Rico*[1]

Soil type and sample No.	Depth	pH
	Inches	
Aguadilla sandy loam:		
5804136	0 - 10	5.7
5804137	10 - 28	5.9
5804138	28 - 48+	8.6
Aguirre clay:		
46	0 - 12	8.7
46	12 - 24	8.4
46	24 - 36	8.5
46	36 - 48	8.9
Alonso clay, smooth phase:		
5802107	0 - 6	5.7
5802108	6 - 20	5.9
5802109	20 - 32	5.8
5802110	32 - 50+	4.9
Amelia clay:		
20	0 - 12	7.7
20	12 - 24	7.9
20	24 - 36	9.7
20	36 - 48	9.2
Bayamón fine sandy loam:		
580277	0 - 10	5.4
580278	10 - 24	5.2
580279	24 - 60	4.7
Catalina clay:		
5802128	0 - 5	5.5
5802129	5 - 20	5.0
5802130	20 - 45+	4.8
Catalina stony clay:		
580345	0 - 7	4.6
580346	7 - 21	4.7
580347	21 - 57	4.8
580348	57+	4.4
Camagüey clay loam:		
5804110	0 - 3	6.3
5804111	3 - 17	8.0
5804112	17 - 35	8.4
5804113	35 - 43+	8.5
Cialitos clay:		
5802131	0 - 6	5.3
5802132	6 - 19	4.7
5802133	19 - 30	5.1
Coloso clay:		
5802148	0 - 6	6.3
5802149	12 - 18	7.4
5802150	24 - 36	7.6
Martín Peña clay:		
5802145	0 - 6	4.2
5802146	6 - 11	4.8
5802147	11 - 29	4.8
Moca clay:		
580468	0 - 8	6.4
580469	8 - 22	5.4
580470	22 - 40	5.9
580471	40 - 60+	6.6
Múcara silty clay loam:		
580341	0 - 11	5.6
580342	11 - 24	7.1
580343	24 - 26	7.1
580344	26+	8.1
Paso Seco silty clay loam:		
12	0 - 12	6.6
12	12 - 24	7.5
12	24 - 36	7.4
12	36 - 48	8.0
Peat:		
580354	0 - 4	5.2
580355	4 - 45+	4.4
Piñones clay:		
580333	0 - 7	4.8
580334	7 - 11	4.8
580335	11 - 40	4.4
Sabana silty clay loam:		
5802125	0 - 5	5.3
5802126	5 - 24	5.8
5802127	24 - 40	5.7
Sabana Seca clay:		
580316	0 - 11	4.6
580317	11 - 23	4.4
580318	23 - 54	4.5
San Antón loam:		
41	0 - 12	8.2
41	12 - 24	8.8
41	24 - 36	8.3
41	36 - 48	8.7
Santa Isabel clay:		
51	0 - 12	8.4
51	12 - 24	8.4
51	24 - 36	9.3
51	36 - 48	9.5
Serrano clay:		
50	0 - 12	9.3
50	12 - 24	8.8
50	24 - 36	8.7
50	36 - 48	8.4
Córcega sandy clay:		
580489	0 - 10	7.9
580490	10 - 20	7.7
580491	20 - 28	8.4
580492	28 - 36	8.6
580493	36 - 60	8.6
Coto clay, heavy phase:		
5804106	0 - 6	6.5
5804107	6 - 17	5.8
5804108	17 40	5.5
5804109	40 - 50+	5.1
Descalabrado silty clay:		
4	0 - 12	7.1
4	12 - 24	7.5
4	24 - 36	7.5
Fajardo clay:		
5802103	0 - 6	4.8
5802104	6 - 12	4.5
5802105	12 - 28	4.3
5802106	28 - 50+	4.1
Guayama clay:		
1	0 - 12	6.6
1	12 - 24	7.1
Guayabo fine sand, shallow phase:		
580455	0 - 16	5.9
580456	16 - 22	6.2
580457	22 - 42	5.0
580458	42 - 60	5.4
Mabí clay:		
5804156	0 - 6	6.9
5804157	6 - 16	6.5
5804158	16 - 30	6.8
Machete clay:		
17	0 - 12	7.2
17	12 - 24	7.4
17	24 - 36	7.1
17	36 - 48	7.1
Matanzas clay:		
580401	0 - 12	5.4
580402	12 - 21	5.3
580403	21 - 34	5.1
580404	34 - 68	5.0
580405	68+	5.2
Maleza loamy sand:		
580410	0 - 9	6.4
580411	9 - 24	5.7
580412	24 - 46	5.4
580413	46 - 60+	5.4
Santa Clara clay:		
5804142	0 - 5	7.8
5804143	5 - 17	7.7
5804144	17 - 24	7.6
5804145	24 - 50	8.4
Teresa clay:		
580688	0 - ½	10.4
580689	½ - 1½	10.3
580690	1½ - 9	9.8
580691	9 - 15	9.0
580692	15 - 30	8.9
580693	30 - 48	8.8
Toa silt loam:		
5804159	0 - 10	6.5
5804160	10 - 50	6.5

[1] Determinations of all the samples designated by 7-digit numbers were made by E. H. Bailey, assistant soil technologist, Division of Soil Survey. The 1- and 2-digit numbers indicate samples on which pH determinations were made by F. A. Villamil, soil chemist, University of Puerto Rico.

TABLE 36.—*pH determinations of some of the more important soils in Puerto Rico*—Continued

Soil type and sample No.	Depth	pH	Soil type and sample No.	Depth	pH
Toa silt loam—Continued.	*Inches*		Vives clay loam—Continued.	*Inches*	
5804161	50 - 70	6.9	27	12-24	7.6
Torres clay:			27	24-36	8.4
5803107	0 - 8	4.7	27	36-48	7.8
5803108	8 - 30	5.0	Yunes clay:		
5803109	30 - 72	4.7	5802141	0- 6	4.6
5803110	72 - 90	4.8	5802142	6- 9	4.1
5803111	90 -108	4.9	5802143	9-30	3.9
5803112	108	5.0	Yunes silt loam:		
5803113	120	4.8	5803115	0- 4	5.1
5803114	144+	5.0	5803116	4-14	4.3
Vives clay loam:			5803117	14-28	4.2
27	0 - 12	6.7			

The Cialitos soils are distinctly red or brownish red, and they are lateritic. They are more permeable and more leached and have a higher content of clay in the A and B horizons than the Múcara, Sabana, or Naranjito soils, and they are developed to a greater depth. They occupy the moister concave slopes at the heads of drains and at the foot of slopes, where water is in contact with the soil and parent rock for a greater length of time than on the steep convex slopes. The Cialitos soils occur on the steep slopes only in areas receiving from 85 to 100 inches of mean annual precipitation.

In the 60- to 75-inch rainfall belt the combination of the natural environmental factors of soil development are favorable for the evolution of Ground-Water Podzols. The prerequisites for the development of such profiles are acid sandy soils having level or undulating relief with restricted internal drainage and some vegetation. As soil formation advances, the soil acidity is intensified as a result of this process. The intermittently moist and arid climate undoubtedly is an important factor. The intensity of the evolution process increases with increasing acidity, sandiness of the surface layer, compaction of the B horizon, and slight depth to ground water. Under the most favorable conditions, the thickness of the organic hardpan layer depends on the relief and the amount of organic matter to be dissolved.

Briefly, this soil-forming process consists essentially of the leaching of organic matter and of soluble salts, including the less soluble carbonates of calcium and magnesium. The colloids become partly or almost completely saturated with hydrogen, after which the soils become strongly acid. The translocation and deposition of humus then takes place. If the surface soils are very sandy, water penetrates rapidly, carrying the dissolved material with it. If the B horizon is very compact, the solution accumulates on its immediate surface, creating a condition favorable for intense leaching of the material a few inches above the compact layer. Field observations show that the layer directly above the compact layer is the lightest in color and generally has a concentration of iron concretions. Soils having heavy clay A horizons and those in the infant stage of evolution to Ground-Water Podzols have a salt-and-pepper sprinkling above the B horizon, but with more favorable conditions the A_2 horizon passes by stages from a thin leached gray layer to a thick structureless white strongly acid layer. As soil development continues, dissolved organic matter and reduced iron are leached to the

compact layer. If there is sufficient slope for favorable lateral movement of the solutions, much of the dissolved organic matter and iron will be carried away by the drainage water, and the organic hardpan may be lacking. If, however, the ground is so level that there is very little lateral movement, the humus as well as the iron will precipitate and accumulate on the compact layer, thereby intensifying the process by retarding or preventing the downward movement of water. If the ground water is high, it may rise to the top of the compact layer, but, on coming in contact with the structureless sandy leached layer, capillary action is reduced and any of the reduced iron in the water will be oxidized and precipitated as perdigón,[30] or iron crust, owing to the large supply of oxygen in the coarse-textured soil.

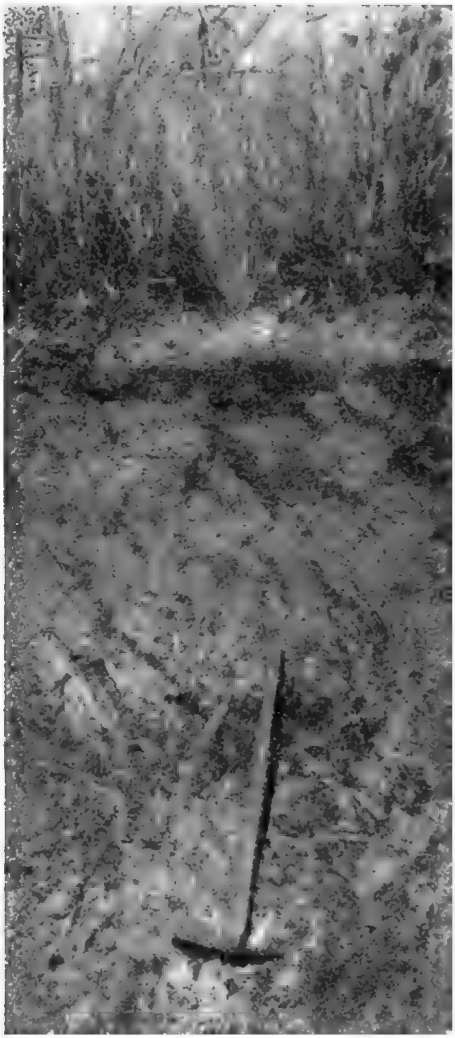

FIGURE 138.—Soil profile of Vega Alta fine sandy loam, showing zone of maximum perdigones, or iron concretions, about 8 inches from the surface. Note the mottling in the lower layers.

Perfil del Vega Alta fino arenoso lómico mostrando la zona de máximo contenido de perdigones o concreciones de hierro, a cerca de 8 pulgadas de la superficie. Nótese el moteado en las capas inferiores.

The evolution of the Ground-Water Podzol can be traced from the Vega Alta soils, especially the sandy-textured members, through the Sabana Seca soils, to the typical Ground-Water Podzol, Corozo fine sand. Other soils that show decided evidence of the influence of ground-water podzolization are areas of the Caguas, Cabo Rojo, Teja, Candelero, Moca, Lares, and Fajardo soils. All these soils are acid, have level or undulating relief, and have compact B horizons.

This kind of podzolization is not necessarily confined to areas having a mean annual rainfall between 60 and 75 inches. Well-developed spots occur in areas receiving as low as 45 inches of rainfall

[30] Perdigones (singular, perdigón) are rounded and irregular-shaped concretions high in iron and generally high in manganese. A literal translation from the Spanish is "ammunition" or "shot."

and as high as 100 inches. The areas in arid districts are developed from strongly acid parent material and possibly were influenced by higher soil moisture during some time in the past.

A rather extensive investigation was made by Thorp and Smith (*44*) concerning the origin of the Corozo sands and related soils of northern Puerto Rico. They described the sands as follows:

The "white sand" deposits consist of white or gray quartz sands which vary in depth from a "smear" of a few inches to dunelike deposits 15 feet or more in thickness. Usually the surface six or eight inches of these sandy areas will be light gray colored while the subsoil will be nearly white. In many places the water table is reached at from 20 to 50 or more inches depth. In these places the white sands are underlain by a heavy, columnar, and highly acid clay which is exceedingly difficult to penetrate with digging tools. This clay is usually gray in color with streaks and blotches of bright red or yellow or both. The thickness of the clay varies and is known to be more than 15 feet deep in places. The cracks and root holes are usually lined with white leached clay (probably kaolin). The sand, where it contacts the clay, is usually stained dark brown or dark gray and is often cemented into a "hardpan." Superficial observation would lead one to believe that this cementing material consists of iron oxides (limonite) but if the "hardpan" is ignited the dark color disappears and leaves a white or sometimes a pale-yellow sand. It is evident, therefore, that the cement is of organic material. In a few places it was observed that the hardpan layer was partly of iron and partly of organic material. When the hardpan from these latter places is ignited the organic part of the cement burns out and the residue, owing to the effect of iron oxide, assumes a light-red or somewhat pink color.

The underlying clay material, when it is exposed in a ditch bank or road cut, exhibits a strong tendency to form vertical columns. These columns break up into well defined prisms of varying sizes which are very hard when dry and exceedingly stiff and resistant to pressure when moist. In the wet condition a good degree of plasticity develops.

There are many places where the white sands lie on knolls or on gently sloping hillsides and a few places where the slope is quite steep. At first sight one would expect that the natural drainage would be good or even excessive in these places. This is frequently true but in many apparently well drained areas there is a heavy, tight clay like that described above which holds up the descending waters after rains and causes the lower layer of white sands to be wet much of the time. In these places, just as in those described in the foregoing, an organic hardpan forms. The places where the white sands have good subdrainage do not have well developed organic hardpans and in some places even dark organic stains are lacking.

Where the white sands are deep they tend to blow up into low dunes and to spread out into layers of varying thickness over adjacent soils. In places where the latter has occurred one does not, of course, find the normal profile development.

Table 37 shows the mechanical analysis of Corozo fine sand. This sand is very similar to Leon sand, which is described by Hearn (*20, pp. 129–136*) and is extensive in southeastern United States, especially in Florida. The exceedingly high percentage of organic matter in the B horizon is owing to the organic hardpan that has accumulated in the nearly impervious B horizon after being leached from the A_1 and A_2 horizons. There has also been some translocation of clay from the A_1 and A_2 horizons to the B horizon, but the percentages of sand separates are about the same in all layers.

TABLE 37.—*Mechanical analysis of Corozo fine sand* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
581015	A_1	0–8	0	1.7	12.6	77.8	5.9	0.7	1.2	1.1	0.4
581016	A_2	8–30	0	1.2	10.1	78.4	8.4	.6	1.2	1.1	0
581017	B	30–36	0	2.4	15.2	55.0	5.1	4.1	18.2	17.5	3.9
581018	C	36+	0	.8	11.0	66.2	5.5	1.0	15.5	14.5	.8

[1] Analyst, H. W. Lakin.

Such soils as those of the Fajardo, Caguas, Sabana Seca, and Vega Alta series are distinctly podzolic but do not have an organic hardpan. The morphology and genesis of these soils are typical for normally developed soils in places where the environmental conditions are favorable for strongly acid soils having restricted drainage at a depth ranging from 15 to 20 inches. With excellent drainage, lateritic soils are developed, but with restricted drainage, ground-water podzolic soils are developed. All these soils show evidence of both podzolization and laterization. The Caguas soils are classed partly as Ground-Water Laterites and partly as Planosols. As mapped they include both great soil groups, because of the complexity of the soil pattern.

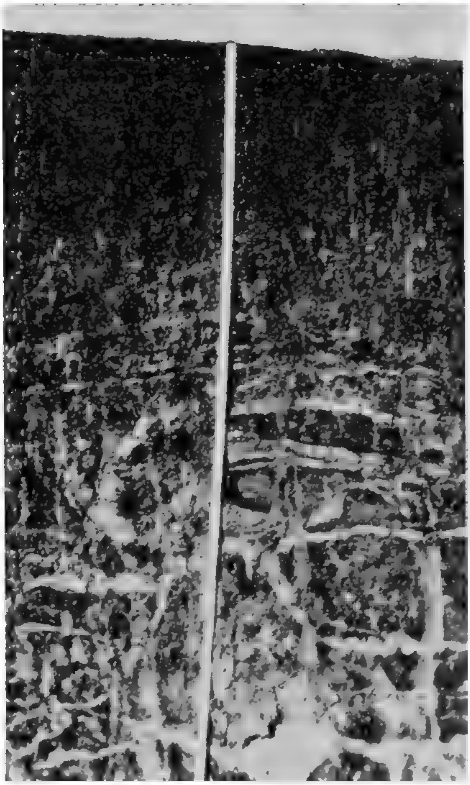

FIGURE 139.—Soil profile of Sabana Seca sandy clay loam showing reticulate mottling. The lighter colored material has a higher content of alumina and clay and a lower content of iron and silica than the darker-colored material. Plant roots are more numerous in the light-colored material because it is more easily penetrated.

Perfil del Sabana Seca areno-arcilloso lómico mostrando el moteado reticular característico. El material de color más claro tiene un contenido más alto de alúmina y arcilla y un contenido más bajo de hierro y silicio que el material más obscuro. Las raíces son más numerosas en el material claro porque es más fácil de penetrar.

The morphologic characteristics common to these soils are (1) a light-colored acid surface soil; (2) an iron concretionary zone (fig. 138), at the base of the A horizon, in which the concretions range from soft black pinhead specks to a mass of circular and irregular-shaped ½-inch concretions cemented together in chunks 2 feet in diameter; (3) a yellowish-brown or reddish-brown heavy acid B horizon; and (4) a reticulately mottled C horizon (fig. 139). The concretionary zone is not distinct in every area, but concretions occur in some place or another in all these soils. Most of the mottles in the C horizon have gray centers surrounded by brown material that grades into dark red.

The Fajardo soils may be considered as normal soils developed on level or undulating relief in a humid climate. They are mostly residual from shales low in bases, but they may have been influenced, to some extent, by material washed from similar shale hills.

A profile of Fajardo clay was observed 5 miles east of Río Piedras. Here the mean annual precipitation is 72.81 inches, ranging from 54.14

to 106.82; and the mean annual temperature is 76.8° F., ranging from 54° to 95°. The soil occupies a nearly level terracelike position at an elevation of about 60 feet above sea level. The vegetation is mostly cerrillo and St. Augustine grass. The parent material is shale or material washed from shale hills. Drainage, both external and internal, is fair. A description of this profile follows.

0 to 6 inches, faintly granular grayish-brown fairly friable clay containing many worm casts and apparently considerable organic matter. Numerous small rounded perdigones, or iron concretions, occur in the lower part.

6 to 12 inches, brown cubical heavy clay, medium compact when dry and medium plastic when wet.

12 to 28 inches, mottled grayish-yellow and red cubical clay. Plant roots tend to be much more numerous in the grayish-yellow material than in the red material. The grayish-yellow material is heavier in texture than the red material and apparently contains less iron and more alumina.

28 to 50 inches, mottled gray and red clay in equal proportions. The gray color becomes more distinct with depth, and the roots are confined almost entirely to the gray material.

This soil does not appear to be poorly drained, but evidently there is enough restriction in the downward percolation of water for podzolization to be more active in some parts of the soil than in others. As water cannot penetrate all the material freely, most of the solutions follow the line of least resistance, namely, the root channels. The decaying roots add organic acids to the solution, and intense leaching takes place in this vicinity. Iron is leached both laterally and downward.

Table 38 shows the results of mechanical analyses of several samples of Fajardo clay. These data show that considerable colloid has been moved from the A horizon and has accumulated in the B horizon. This has been brought about by the soil-developing process of podzolization.

TABLE 38.—*Mechanical analysis of Fajardo clay* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802103	A	0–6	2.6	3.3	1.6	2.9	4.2	17.2	68.2	57.1	4.7
5802104	B_1	6–12	.1	.2	.2	.8	2.6	13.2	82.9	73.5	1.3
5802105	B_2	12–28	.1	.1	.1	.8	3.2	16.9	78.9	69.1	1.0
5802106	C	28–50	.0	.1	.2	1.1	3.4	16.6	78.6	66.5	.5

[1] Analyst, H. W. Lakin.

Table 39 gives the chemical analysis of the whole soil of Fajardo clay. The data show an unvaried composition of the three horizons. Compared with the lateritic Coto clay, this soil has a higher content of bases and silica but a much lower content of iron and alumina. The phosphorus content is exceedingly low.

TABLE 39.—*Chemical analysis of Fajardo clay* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
5802103	A	0–6	69.07	7.33	11.14	0.43	0.25	0.18	0.03	0.75	0.73	0.07	0.13	9.80	99.91	4.71	0	0.25
5802104	B_1	6–12	65.88	7.70	16.65	.57	.16	.42	.08	.74	.04	.05	.09	7.83	100.21	1.14	0	.10
5802105	B_2	12–28	64.60	8.74	16.82	.75	.07	.49	.07	.78	.04	.07	.16	7.73	100.32	.77	0	.07
5802106	C	28–50	65.01	7.56	18.00	.67	.07	.60	.01	.74	.03	.09	.18	7.15	100.11	.37	0	.04

[1] Analyst, G. Edgington.

The chemical analysis of the colloid, as shown in table 40, gives a more instructive picture. Iron has accumulated in the B horizon, apparently by leaching from the A horizon during the rainy season and because of an upward movement of moisture from the C horizon during the dry season. The bases are considerably higher in the colloid than in the whole soil.

TABLE 40.—*Chemical analysis of Fajardo clay colloid* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
5802103	A	0–6	46.81	9.18	25.39	0.83	0.20	0.26	0.11	0.92	0.51	0.13	0.17	15.72	100.23	3.15	0	0.39
5802104	B_1	6–12	45.17	12.61	26.82	.90	.28	.29	.05	1.13	.06	.07	.08	12.87	100.33	.90	0	.17
5802105	B_2	12–28	46.93	12.51	26.54	.96	.15	.60	.04	.91	.06	.06	.10	11.59	100.45	1.20	0	.09
5802106	C	28–50	51.62	8.83	26.05	1.11	.25	.78	(2)	.87	.05	.05	.08	10.84	100.53	1.14	0	.07

[1] Analyst, G. Edgington. [2] Trace.

The derived data for the Fajardo clay colloid are shown in table 41. The silica-iron oxide ratios indicate considerable translocation of iron oxide to the B horizons.

TABLE 41.—*Derived data: Fajardo clay colloid*

Sample No.	Horizon	Depth	Molecular ratio					Water of hydration
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	
		Inches						*Percent*
5802103	A	0–6	2.54	13.55	3.13	0.231	27.2	12.57
5802104	B_1	6–12	2.20	9.52	2.86	.301	23.7	11.97
5802105	B_2	12–28	2.31	9.98	3.00	.301	23.3	10.79
5802106	C	28–50	2.77	15.54	3.36	.216	21.5	9.70

The Caguas soils have developed from material washed from upland hills centuries ago. They are old alluvial fans or coastal plains. The area near Ceiba evidently was formed by material washed from the lateritic soil-covered mountainous lands to the west. Much of the Caguas soil as mapped has the typical morphology of a Ground-Water Laterite.

Caguas clay has relief, vegetation, climate, and surface drainage similar to those of Fajardo clay. The surface soil is much lighter colored, the perdigón layer generally is more conspicuous and thicker, and the B horizon is more compact; therefore internal drainage is not so good as in Fajardo clay. The B and C horizons have a fragmentary structure, but the gray and red mottlings are as distinct as in Fajardo clay.

Table 42 gives the mechanical analyses of samples of Caguas clay, collected one-half mile northwest of Ceiba. The analyses indicate that this sample does not have a clay surface soil. It is thought, however, that most of the soil, as mapped, does have a clay surface soil. The high percentage of fine gravel in the A horizon evidently is

caused by iron concretions, which were not considered by the field men in their texture determination. This soil does not contain shale or rock fragments, but it does have a large number of iron concretions, ranging from one-eighth to one-fourth inch in diameter, at the base of the surface layer. This analysis shows that there is an illuviated B horizon. The organic matter is very low, although the sample was taken in a pasture that previously had been cultivated.

TABLE 42.—*Mechanical analysis of Caguas clay* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter by H_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
580399	A	0–7	12.8	8.0	2.8	5.8	8.4	35.9	26.4	19.2	0.8
5803100	B	7–20	1.8	1.9	1.2	2.8	4.5	22.7	65.2	59.5	.7
5803101	C	20–48	1.6	3.7	3.3	6.2	6.4	16.1	62.8	57.6	0

[1] Analyst, H. W. Lakin.

Table 43 gives the chemical analysis of the colloid of Caguas clay. Compared with the colloid of the Fajardo soil, this soil has a lower silica, magnesium, potassium, and sodium content but a higher iron and manganese content.

TABLE 43.—*Chemical analysis of Caguas clay colloid* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
580399	A	0–7	34.35	17.37	26.40	0.73	0.58	0.19	0.03	1.38	2.27	0.17	0.10	16.68	100.25	3.10	0	0.38
5803100	B	7–20	36.40	17.36	29.44	.78	.37	.15	.08	1.03	.06	.03	.03	13.93	99.66	.58	0	.18
5803101	C	20–48	39.59	13.21	30.84	.80	.43	.14	.05	.92	.04	.02	.07	13.47	99.58	.27	0	.17

[1] Analyst, G. Edgington.

Table 44 gives the derived data of the Caguas clay colloid. It shows that this soil has probably been influenced by both laterization and podzolization. The low silica-sesquioxide ratio, as well as the low silica-alumina ratio, indicates laterization, but it must be remembered that the methods of analysis do not allow the exact determination of the amounts of free and combined silica in the colloids.

TABLE 44.—*Derived data: Caguas clay colloid*

Sample No.	Horizon	Depth	Molecular ratio					Water of hydration
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	
		Inches						*Percent*
580399	A	0–7	1.55	3.28	2.21	0.424	18.3	13.58
5803100	B	7–20	1.52	5.57	2.10	.371	20.9	13.35
5803101	C	20–48	1.71	7.96	2.18	.274	31.1	13.20

The Vega Alta soils are more closely associated with the Reddish-Brown and Yellowish-Brown lateritic soils, such as the Bayamón, Espinosa, Coto, and Matanzas soils, than are either the Fajardo or the Caguas soils. The typical Vega Alta soils are derived from limestone, and those with a heavy-subsoil phase probably are influenced somewhat by clayey materials.

A profile of a cultivated area of Vega Alta fine sandy loam was observed 3 miles southeast of Vega Alta, where the mean annual precipitation is about 75 inches, the mean annual temperature about 75° F., the relief undulating, and the elevation about 100 feet. The drainage appears to be good, but the mottled condition of the C horizon indicates restricted drainage. A description of this profile follows.

0 to 10 inches, yellowish-brown massive very loose friable acid fine sandy loam containing many insect casts.
10 to 12 inches, a leached layer of light-yellow or gray gritty sandy loam showing evidence of podzolization.
12 to 30 inches, yellowish-brown acid slightly compact sandy clay with perdigones scattered through the upper inch or two.
30 to 48 inches, mottled red, yellowish-brown, and gray heavy but fairly permeable clay. The brown color predominates.
48 to 100 inches, mottled gray and deep-red clay with some brown splotches. The mottling is distinct in this layer and is of a well-defined gray color bordered with brown and this, in turn, with red. Plant roots are numerous in the gray material both in this layer and in the layer above.

The B and C horizons of a profile of this soil and similar soils derived from limestone have a peculiar convex bulging when exposed for a long time, as in road cuts or ditch banks. The surface soil is more readily eroded than the lower layers, and consequently the walls of the banks are not perpendicular.

The mechanical analysis of Vega Alta fine sandy loam and separate analyses of the mottlings of brown, gray, and red material, taken at depths between 84 and 100 inches, are shown in table 45. The mechanical analyses of this sample are similar to those of other samples of soil derived from limestone, such as the Coto, Bayamón, and Matanzas soils, in that a very high percentage of the clay is colloid and the silt content is very low. They show that the gray material is considerably higher in clay than is the red material.

TABLE 45.—*Mechanical analysis of Vega Alta fine sandy loam* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
581076	A_1	0–10	0.1	3.7	10.7	55.8	15.5	3.7	10.6	9.6	0.1
581077	A_2	10–12	.4	5.0	11.3	53.2	13.9	3.9	12.3	11.7	0
581078	B_1	12–30	.7	4.0	8.8	42.3	12.0	5.5	26.6	26.6	.6
581079	B_2	30–48	1.8	4.9	5.4	17.2	5.5	4.0	61.1	60.2	.5
581080	C	84–100	.8	4.8	6.2	24.1	7.2	4.9	52.1	51.1	0
581081	[2]	84–100	.5	3.4	6.1	24.2	6.5	1.5	57.8	57.8	0
581082	[3]	84–100	.2	3.7	6.6	25.5	6.6	.8	56.6	56.6	0
581083	[4]	84–100	.8	4.7	6.6	24.9	7.1	3.6	52.2	51.6	0

[1] Analyst, H. W. Lakin. [2] Brown material. [3] Gray material. [4] Red material.

The chemical analysis of Vega Alta fine sandy loam is shown in table 46. These data show that the A_1 and A_2 horizons have been leached of considerable iron and alumina and that accumulation of iron has taken place in the B_2 horizon, as might be expected in a podzolized soil. There has also been considerable leaching of iron in the gray material, as it has about one-sixth as much iron as the red material and about one-fourth as much as the brown material. The alumina content is highest in the gray and lowest in the red material of the mottlings. The potassium, one of the limiting elements in plant production, is highest in the gray material.

TABLE 46.—*Chemical analysis of Vega Alta fine sandy loam* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
581076	A_1	0–10	92.32	1.59	3.23	0.06	0.04	0.01	(2)	0.68	0.04	0.01	0.03	1.79	99.80	0.55	0	0.03
581077	A_2	10–12	91.49	1.85	3.75	.05	.04	.01	(2)	.73	.03	.02	.02	2.01	100.00	.51	0	.02
581078	B_1	12–30	79.49	4.75	9.64	.16	.07	.05	(2)	.90	.04	.01	.18	4.73	100.02	.47	0	.05
581079	B_2	30–48	55.96	10.41	21.75	.12	.07	.15	(2)	1.00	.04	.03	.04	10.15	99.72	.53	0	.05
581080	C	84–100	61.49	9.55	19.73	.02	.12	.16	(2)	.88	.05	.01	.16	7.88	100.05	.16	0	.03
581081	(3)	84 100	63.19	5.39	21.88	.13	.16	.13	(2)	.93	.04	.02	.12	8.49	100.48	.30	0	.05
581082	(4)	84–100	67.72	1.49	22.15	.03	.12	.15	(2)	1.01	.02	.03	.08	7.67	100.47	.14	0	.03
581083	(5)	84–100	62.68	9.72	18.69	.02	.15	.09	(2)	.83	.05	.03	.17	7.55	99.98	.16	0	.03

[1] Analyst, G. Edgington. [2] Trace. [3] Brown material. [4] Gray material. [5] Red material.

The gray layer probably is more easily penetrated by plant roots, as it is in general more moist, and, although more plastic, it is not so compact as either the brown or the red material. There is some evidence that it contains more plant nutrients than the red material, and therefore the roots would develop better than in the less nutritious layers. After the roots are once established, the podzolization process is increased by the driving force of the larger quantity of more acid solutions following the root channels. The decaying roots intensify the acidity of the solution.

Table 47 shows the results of mechanical analysis of samples of a profile of Vega Alta sandy clay loam, heavy-subsoil phase, and separates of the red and gray material of the mottlings at two depths. In physical characteristics this profile is similar to that of the Caguas soils, and it has been influenced by clayey coastal-plain material, which, probably, was not derived entirely from limestone. The silt content is slightly higher than in the typical Vega Alta soils. The B_2 is the heaviest layer, as is true with Vega Alta fine sandy loam. The same correlation exists between the clay content of the red and gray material at each of the two depths of this soil examined, as occurs in Vega Alta fine sandy loam. In this sample both the clay content and the organic matter are higher in the gray material than in the red material.

TABLE 47.—*Mechanical analysis of Vega Alta sandy clay loam, heavy-subsoil phase* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802111	A	0–9	3.5	16.8	10.9	14.2	8.3	14.5	31.8	28.2	3.1
5802112	B_2	9–21	8.2	12.0	7.0	9.8	6.5	10.5	46.0	43.4	.9
5802113	B_2	21–45	.7	2.5	3.1	7.5	4.3	6.1	75.8	73.4	.9
5802114	C	45–60+	.3	.8	1.9	9.4	7.4	11.7	68.4	64.1	.1
5802137	[2]	45	3.1	7.4	5.0	11.7	8.1	15.3	49.4	44.0	.1
5802138	[3]	45	.1	.6	1.4	8.9	7.0	10.8	71.2	66.2	.4
5802139	[2]	60	8.7	21.0	11.4	10.0	4.2	8.2	36.5	34.3	0
5802140	[3]	60	10.8	16.7	8.1	6.4	2.8	5.3	49.9	48.0	.2

[1] Analyst, H. W. Lakin. [2] Red material. [3] Gray material.

Table 48 gives the chemical analysis of the red and gray materials of Vega Alta sandy clay loam, heavy-subsoil phase. The same correlation exists in this analysis as was conspicuous in the chemical analyses of the different colored materials in Vega Alta fine sandy loam. Potassium and alumina are much higher in the gray material, and iron and silica are higher in the red material. From the chemical data and field observations it appears that podzolization is, for the most part, the cause, in the mottled red, brown, and gray layers, of separation of the iron compounds from the alumina in some places, under the influence of percolating water, as suggested by Marbut.[30]

TABLE 48.—*Chemical analysis of red and gray material of the reticulate layer of Vega Alta sandy clay loam, heavy-subsoil phase* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
5802137	Red layer	45	52.26	19.87	19.62	0.20	0.25	0.16	0	0.55	0.02	0.13	0.16	7.67	100.89	0	0.03
5802138	Gray layer	45	56.64	5.39	26.32	.58	.14	.25	0	.86	.02	.06	.10	9.52	99.88	0	.03
5802139	Red layer	60	74.30	9.07	11.61	.46	.18	.14	0	.60	.03	.04	.14	4.44	101.01	0	.03
5802140	Gray layer	60	72.41	2.28	17.82	.45	.18	.20	0	.66	.01	.05	.11	6.50	100.67	0	.006

[1] Analyst, G. J. Hough.

Thorp (*43, p. 308*), makes this statement:

It seems probable to me that segregation of iron in the soils of tropical regions begins under conditions of imperfect drainage, possibly even under conditions of waterlogging. In poorly drained areas, especially if there is a period in each year when the soil partially dries out, segregation of iron takes place very rapidly. This is very apparent in all of the rice paddy soils except a few on which the water stands the entire year. In southern United States and Puerto Rico and, from the writings of investigators, in other subtropical and tropical regions as well, the development of reticulate mottling is characteristic of soils in flat areas where drainage is restricted, but the soil not actually waterlogged the entire year. These flat areas may be on low river terraces or plains, or on high plateaus. Drainage conditions are rendered imperfect by the flat topography regardless of whether it occurs on low or high elevations. Soils in these positions usually have well-defined podzolic profiles (so far as morphology is concerned) with grayish A horizons yellowish B horizons, and red, gray, and yellow parent clays. In this stage of

[30] MARBUT, C. F. SOILS, THEIR GENESIS, CLASSIFICATION, AND DEVELOPMENT. Lectures delivered in U. S. Dept. Agr. Grad. School, Lecture 18, pp. 4–5. 1928. [Mimeographed.]

development they are usually very plastic and therefore probably belong to Harrassowitz's siallites. Many soil series showing variations of this type of profile have been established in the United States and the West Indies and, more recently, in China.

Table 49 gives the chemical composition of four samples of iron concretions, or perdigones, collected from four different soil types. The perdigones vary greatly, both physically and chemically. They range from hard to soft, from round to unsymmetrical, from microscopic to cemented masses 2 feet in diameter, and from red to black. Some are concentric, and others are massive. In places ironpans and slaglike iron pieces occur, either with or without the iron concretions. In places rocks exposed to the air are coated with an incrustation of material similar in composition to the concretions. As indicated by the analyses, the iron content is high, as also is that shown by the analyses of a large number of samples collected by Bennett and Allison (*8*) in Cuba, and Thorp (*43*) in China. The manganese is exceedingly high in two samples, and most of the samples are rich in phosphorus. The concretions having the highest calcium oxide content occur in the most alkaline of the four soils. The most sandy soil contains concretions with the highest silica content.

TABLE 49.—*Chemical analysis of perdigón from several soils* [1]

Sample No.	Soil type	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
36978	Vega Alta clay, heavy-subsoil phase.	31.58	11.62	24.69	0.18	0.19	0.12	0.10	0.80	15.98	0.02	0.26	14.71	100.25	0.08	0	0.05
36977	Fajardo clay	44.67	17.80	16.50	.31	.19	.24	.05	.90	9.10	.01	.23	10.13	100.13	.41	0	.01
36970	Santa Clara clay.	33.63	51.34	5.00	.10	.46	.23	.04	.42	.23	.34	.08	8.67	100.54	.25	0	.01
36969	Sabana Seca sandy clay loam.	70.61	17.53	5.38	.01	.35	.10	(2)	.64	.11	.98	.07	4.46	100.24	.13	0	.02

[1] Analyst, G. Edgington. [2] Trace.

An abundance of concretions is nearly everywhere a good indicator of soils low in bases, but some of these soils will respond to fertilizer (*9b, 9c*). Soils with many concretions on the surface or near the surface indicate that the surface soil has been partly or completely removed, as the concretions normally occur near the top of the B horizon and are not noticeable unless erosion has been serious. In general, these are poor agricultural soils. They are difficult to cultivate and produce low yields, not entirely because of chemical conditions but because the surface soil has been removed and the compact B horizon is near the surface.

Table 50 gives the mechanical analysis of Vega Baja clay, a soil influenced by coastal-plain material and alluvium. It occupies a position midway between the Vega Alta soils and the alluvial Coloso soils. It occurs slightly above normal overflow but may be inundated during exceedingly high water. The silt content is considerably higher

than in the previously described soils, indicating that the material is less maturely weathered. The clay content of the C horizon is much lower than in either the A or B horizon.

TABLE 50.—*Mechanical analysis of Vega Baja clay* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802122	A	0–7	1.2	4.8	4.9	10.0	8.3	24.0	46.8	38.2	3.9
5802123	B	7–30	.1	1.1	3.4	9.8	8.8	24.8	52.1	41.8	.7
5802124	C	30–60	4.3	16.1	8.5	8.2	7.0	21.7	34.2	24.4	.4

[1] Analyst, H. W. Lakin.

Table 51 gives the mechanical analysis of Coloso clay, a poorly drained azonal alluvial soil.

TABLE 51.—*Mechanical analysis of Coloso clay* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5804149	1	0–12	0.3	0.4	0.6	2.7	5.4	28.6	61.9	49.3	2.0
5804150	2	12–30	.2	2.0	3.0	8.0	9.0	27.8	50.0	40.4	1.0

[1] Analyst, H. W. Lakin.

One of the outstanding topographic characteristics of the northwestern coastal plains, where the lateritic soils dominate, is the precipitous saw-toothed limestone hills locally called mogote (haystack) or pepino (cucumber) hills. These peculiar hills and the intervening undulating plains, with their thousands of sinkholes, make up what is technically known as Karst topography. The name comes from the Karst Mountains of Austria. The soils of most of these brush-covered jagged hills are classified as Tanamá stony clay, a reddish-brown or red neutral or slightly acid soil, in a few places more than 3 inches thick, underlain by hard Tertiary limestone. Many of the hills are small and haystacklike, and others range up to 300 feet in height. They generally occur in long east-west chains, with intervening smoothly undulating valleys having fairly fertile red or yellow deep soils.

Viewed from a distance, the tops of the hills resemble the teeth of a saw. The high points of the saw-tooth hills trend toward the west-southwest. The parent rock is susceptible to atmospheric attack, which is intensified on the east and north, owing to greater precipitation caused by the prevailing northeast trade winds. The greater precipitation is also favorable for a more vigorous plant growth on the north and east slopes, therefore more humic acid is released, and this has a great effect in dissolving and decomposing the limestone, thereby helping to form the peculiar saw-toothed relief. Thorp (*42*) states that the Tertiary limestones in the coastal plain of northern Puerto Rico are characteristically eroded into rugged conical hills, most of which have a distinctive asymmetric cross section. The

asymmetry is systematically oriented with respect to the trade winds, and its origin appears to be due, in a large part, to differential solution promoted by rains borne in from the east-northeast by the trade winds.

THE 75- TO 95-INCH RAINFALL BELT

The 75- to 95-inch rainfall belt includes an area of the mountainous interior equally as large as the combined areas of all the other rainfall belts. Viewed from the air at a high elevation, this area resembles a gigantic deflated balloon. The mountains have been faulted (fig. 140) and tilted by earthquakes, stratified from the effects of century-old volcanos, serrated and dissected by thousands of rivulets, and scarred by hurricanes. Geologically, the most abundant rocks are various forms of volcanic tuff, although granites, shales, serpentine, and limestone are locally important.

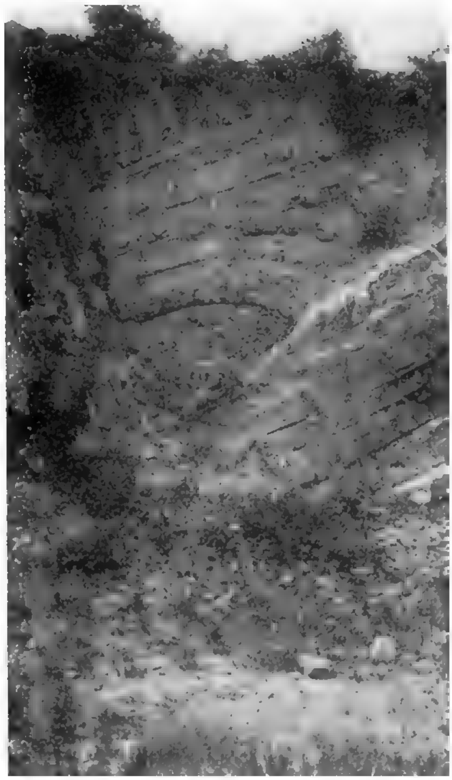

FIGURE 140.—Small fault showing disturbance in the shale.

Pequeña falta mostrando alteración local en el esquisto.

Nearly all of the vegetation is mesophytic, and under the humid climate it grows rapidly and densely. The moist tropical climate is nearly ideal for rapid weathering of the rocks, and most of the soils, except those on exceedingly steep slopes, are deep. The high rainfall has had a destructive leaching effect on the soils, and most of them are deficient in calcium, magnesium, and phosphorus. The land is owned by small landowners who seldom apply amendments, and the grains and grasses produced are apparently low in nutrition. Rickets and poor teeth are more prevalent among the people in this area than in areas where the rainfall is less.

Laterization is the dominant active process in the evolution of most of the soils in this district, although typical Rendzinas and soils closely resembling Gray-Brown Podzolic soils are developed in places where the combination of environmental factors is favorable for their development. Medium to soft impure limestone is favorable for the development of Rendzinas. Strongly acid soils resembling the Gray-Brown Podzolic soils are developed on smooth relief where drainage is somewhat restricted and the parent material is strongly acid, as in some of the shales. Yunes clay is one of the best representatives of this group. Yunes silt loam, a similar soil, occurs in areas having 20 inches less precipita-

tion. The physical characteristics of the two soils are nearly identical, but the chemical analyses show considerable difference but no more than might be expected, considering the differences in normal soil development, owing to difference in soil moisture. Both of these soils are used mostly for pasture. The vegetation is much heavier on Yunes clay, but the grass on Yunes silt loam is considered slightly more nutritious. As may be expected, with a difference of 20 inches of rainfall, Yunes clay is more acid, although both are acid soils, owing to the low content of soluble bases in the parent shale rock. These soils occur within a few miles of each other.

Samples of Yunes clay were collected on a steep slope near Observatorio Naval, at an elevation of about 200 feet above sea level. The mean annual precipitation here is about 80 inches and the mean annual temperature about 75° F. The vegetation consists of mesophytic plants. Drainage is good. The parent rock is shale.

0 to 6 inches, dark-gray friable acid clay.
6 to 9 inches, light-gray acid clay, which is friable when dry but plastic when wet.
9 to 30 inches, reddish-brown plastic clay mixed with shale fragments.
30 inches +, grayish-brown shale rock.

Table 52 gives the mechanical analysis of Yunes clay. It shows that the A horizon has the highest content of clay and the B horizon the lowest content.

TABLE 52.—*Mechanical analysis of Yunes clay* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802141	A	0– 6	2.1	2.7	1.2	2.1	2.7	14.9	74.3	57.2	8.1
5802142	B	6– 9	5.2	4.6	1.5	1.9	2.6	17.0	67.3	50.1	1.2
5802143	C	9–30	4.6	3.4	1.2	1.6	2.2	18.5	68.5	55.5	.8

[1] Analyst, H. W. Lakin.

Table 53 gives the chemical analyses of the three horizons of Yunes clay. The high content of silica in the B horizon is due to the higher content of sands in this layer, as shown by the mechanical analyses. The iron content of the B horizon is nearly twice as great as that in either of the other layers, indicating podzolization. The bases are exceedingly low but not so low as in either the lateritic Coto soils or the Laterite, Nipe clay.

TABLE 53.—*Chemical analysis of Yunes clay* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
5802141	A	0– 6	78.22	1.02	8.63	0.01	0.23	0.11	(2)	0.47	0.01	0.06	0.12	11.11	99.99	5.18	0	0.34
5802142	B	6– 9	81.60	2.06	10.24	(2)	.17	.17	(2)	.40	.01	.03	.06	4.91	99.65	.76	0	.04
5802143	C	9–30	73.47	1.18	17.51	(2)	.15	.08	0.01	.61	.02	.06	.07	6.82	99.98	.42	0	.02

[1] Analyst, G. Edgington. [2] Trace.

As previously described, an iron hardpan has been developed in many areas of Yunes silt loam. A sample of this soil occurring near Fajardo, where the annual rainfall is about 55 inches, has profile characteristics as follows:

0 to 4 inches, dark-gray loose friable silt loam containing a high percentage of sharp angular shale fragments which weather very slowly.

4 to 14 inches, gray silt loam, which is slightly heavier, more plastic, and more cemented than the material in the layer above. It contains many shale fragments that are larger than those in the A horizon.

14 to 28 inches, cemented light-yellow heavy silt loam, which is hard to crush between the fingers. When exposed to the hot climate the material becomes brownish red and more indurated. This layer cannot be bored through with a soil auger. It rests on fragments of gray acid shale.

Many areas of this soil, from which the surface soil has eroded, have the cemented layer exposed.

Table 54 gives the mechanical analysis of Yunes silt loam. Owing to the high content (more than 62 percent) of shale fragments in the A and B horizons, the content of fine gravel is considerably higher than would be possible for a silt loam, but the soil material has a distinctly silt loam texture when examined in the field. Many areas do not have so large a proportion of shale fragments as does this profile. The colloid content of the C horizon is low in comparison with the clay content, indicating faint soil development.

TABLE 54.—*Mechanical analysis of Yunes silt loam* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5803115	A	0–4	46.4	13.6	3.3	3.8	3.3	10.7	18.8	13.8	6.0
5803116	B	4–14	22.9	9.1	3.6	5.3	6.2	19.0	33.8	24.0	2.6
5803117	C	14–28	4.5	5.7	3.5	8.1	12.3	28.3	37.6	18.5	.4

[1] Analyst, H. W. Lakin.

The chemical analysis of Yunes silt loam is shown in table 55.

TABLE 55.—*Chemical analysis of Yunes silt loam* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
5803115	A	0–4	87.82	3.43	4.38	0.29	0.11	0.65	(2)	0.36	0.01	0.14	0.17	2.78	100.14	0.98	0	0.09
5803116	B	4–14	88.89	3.37	3.43	.26	.03	.42	(2)	.40	.01	.12	.16	2.53	99.62	1.17	0	.07
5803117	C	14–28	84.57	5.41	5.29	.28	.05	.62	(2)	.91	.02	.15	.13	2.50	99.93	.28	0	.05

[1] Analyst, G. Edgington. [2] Trace.

The data clearly show that soil development is much less active in this area and on this kind of rock than in the area of much higher rainfall where the samples of Yunes clay were collected. All the bases, except calcium, are much higher in this soil than in Yunes clay. Calcium is high in Yunes clay because the greater abundance of vege-

tation adds more to the surface soil than does the sparse vegetation in this area of Yunes silt loam. Phosphorus is much higher in this sample and, as could be expected, the pH value is higher and the organic matter less, owing to lack of vegetation. If this analysis is compared with an analysis of a sample of soil derived from tuffaceous rocks in the same rainfall area, it may be seen that the content of bases is very much lower: (1) Because the tuffaceous rocks are higher in bases and (2) because the material developed from tuffaceous rocks is more permeable, therefore the soil moisture acts for much less time than in the plastic soils derived from shale. The content of moisture in the B horizon of the Yunes soils is sufficient for more continuous soil-forming activity than in the friable B horizon of the Descalabrado soils, which are derived from tuffaceous rock. The Descalabrado soils generally are dry and show very little biochemical activity.

The C_1 horizon of Yunes silt loam contains nearly twice as much iron as the B horizon, but it is not sufficient to account for the cemented iron layer, without the combined high acidity and low soil moisture. The cemented layer is not developed in Yunes clay in places where the rainfall is higher and vegetation more dense, although the pH value is low in Yunes clay.

The selenium content of these two soils, as well as of associated soils derived from Cretaceous rock, is reported by Byers, Miller, Williams, and Lakin (*11*). Table 56 shows the content of selenium in the Yunes soils. The content of selenium is sufficiently high in the parent rock of Yunes silt loam to produce toxicity in the plants under favorable conditions, but many deep-rooted and shallow-rooted plants have been analyzed, and no appreciable amount of selenium was found. This would indicate that in these strongly acid soils the free ferric hydroxide probably prevents extensive absorption of selenium by plants.

TABLE 56.—*Selenium content of the Yunes soils* [1]

Soil type	Soil survey No.	Laboratory No.	Depth	Selenium	Soil type	Soil survey No.	Laboratory No.	Depth	Selenium
			Inches	*Parts per million*				*Inches*	*Parts per million*
Yunes clay	5802141	B 2997	0- 6	1.0	Yunes silt loam	5803115	B 3000	0- 4	1.5
Do	5802142	B 2998	6- 9	1.5	Do	5803116	B 3001	4-18	2.0
Do	5802143	B 2999	9-30	1.5	Do	5803117	B 3002	18-28	10.0

[1] Yunes clay receives approximately 80 inches of rainfall and Yunes silt loam 55 inches.

Some plants, such as zarzarilla (*Leptoglottis portoricensis*), undoubtedly cause animals to lose their hair when the main diet consists of this shrub, but all analyses fail to show sufficient quantities of selenium in the plant to cause a toxic effect. The loss of hair is not followed by deformed hoofs or other symptoms so characteristic of selenium poisoning throughout certain districts in west-central United States.

The Rendzinas are best represented by the Soller soils, which consist of an 8- or 10-inch layer of black granular clay overlying white or

yellowish-white soft friable limestone that grades into fairly hard Lares limestone at a depth ranging from 12 to 16 inches. This soil has a high biological pressure and is very high in organic matter, but it is susceptible to sheet erosion on slopes exceeding 7 percent.

These soils are waxy and plastic when wet and are hard and dense when dry. During the dry season, cracks 2 inches wide extend from the surface to a depth of several inches. Similar soils occur in Santo Domingo, Saint Croix (*40*), Cuba, China, and southern United States (*30*).

Rendzinas are considered intrazonal soils, because their dark color is maintained only on account of an abnormally high content of calcium ion that is continually being released in the surface soil from the decomposition of vegetation, generally grass, high in this element, which has been assimilated by the lower roots of the plants. They differ radically from the zonal soils, with which they are associated.

The Soller soils occur on relief ranging from level to hilly in a rainfall belt ranging from 90 to 110 inches, but the Rendzinas also include soils, such as members of the Colinas and Aguilita series, in much drier areas.

Closely associated with the Soller soils is the Dominguito soil, a Reddish Prairie soil. This soil is derived from older Tertiary clays, but it has been influenced to some extent by limestone outcrops. It occurs on undulating relief. Samples of a profile of Dominguito clay, collected at Kilometer 3.7 on the Ciales-Morovis road, show the following:

0 to 7 inches, black slightly granular clay containing many worm casts. The material in this layer is plastic and sticky when wet.
7 to 14 inches, mottled light-brown and red plastic sticky clay, which generally is moist, even during dry periods, and sticks to the auger.
14 to 40 inches, sticky plastic mottled bright-red and gray clay.
40 to 60 inches, gray and yellowish-gray sticky plastic clay, more alkaline than the clay in the layer above.

Table 57 gives the mechanical analysis of Dominguito clay. The profile shows very little variation in texture, except that the coarser material in the upper horizons evidently has broken down to fine particles in the lower horizons. The movement of colloids evidently has been very slow, compared with that feature of many of the soils previously described.

TABLE 57.—*Mechanical analysis of Dominguito clay* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
581205	A	0–7	0.3	0.5	0.5	9.6	16.8	19.0	53.2	50.9	7.3
581206	B	7–14	.0	.0	.0	8.1	20.1	10.5	61.3	61.0	.6
581207	C	14–40	.0	.0	.1	5.3	13.0	13.2	68.4	67.2	....

[1] Analyst, H. W. Lakin.

In table 58 are shown the results of chemical analyses of the colloid of Dominguito clay.

TABLE 58.—*Chemical analysis of Dominguito clay colloid* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
581205	A	0–7	43.87	10.03	23.61	2.42	1.27	0.52	0.06	0.67	0.05	0.23	0.07	17.62	100.42	4.39	0	0.52
581206	B	7–14	46.79	11.90	23.84	2.42	1.01	.34	.11	.72	.04	.01	.04	12.70	99.92	1.60	0	.18
581207	C	14–40	47.51	11.81	23.43	2.51	1.48	.37	.06	.69	.03	.04	.02	11.68	99.63	.87	0	.14

[1] Analyst, G. Edgington.

The percentages of magnesium oxide, sodium oxide, titanium oxide, manganese oxide, and phosphorus remain essentially constant in three layers. The first and third horizons are higher in calcium than is the B horizon. This is characteristic of most Reddish Prairie soils, as calcium is an important mineral constituent of the grasses and the accumulation in the A horizon may be attributed to residue from decayed grasses. The increase in calcium in the C horizon is due to small lime specks, as noted in the field examination. The potassium content, although much higher than in the soils previously discussed, is much lower than in the Carrington soil of the Prairie soils region of the United States. This would indicate that the Dominguito soil is leached to a greater extent than the Carrington. The organic content of 4.39 percent in the colloid shows that zonal soils in the tropical region can have a high content of humus, even in well-aerated soils.

Table 59 gives the derived data from the composition of colloid of Dominguito clay. The ratios are fairly consistent in all three horizons, as is true with most Prairie soils.

TABLE 59.—*Derived data: Dominguito clay colloid*

Sample No.	Horizon	Depth	Molecular ratio					Water of hydration
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	
		Inches						*Percent*
581205	A	0–7	2.48	11.61	3.15	0.252	8.58	13.23
581206	B	7–14	2.53	10.43	3.33	.324	9.83	11.10
581207	C	14–40	2.60	10.68	3.44	.323	8.43	10.81

Many soils that are strongly lateritized occur within the 75- to 95-inch rainfall belt. Among them are those of the Catalina, Cialitos, Alonso, Rosario, and Nipe series. Nipe clay apparently is the end product of laterization. According to Vageler (*47, p. 167*), this soil probably could be classified as a fossil soil. From all general appearances it is inert, and soil development has ceased. There is, however, some biological activity, which seems to be confined to the upper few inches of soil, which contains the greatest amount of organic matter. This soil is not sterile, but it is extremely infertile unless large quantities of lime and fertilizers high in phosphorus are applied yearly.

A description of a typical profile of this soil has been given by Roberts (*36*) and is repeated here with a few modifications.

On a mesa southeast of Mayagüez, where the rainfall exceeds 80 inches, is an area of high rounded hills derived from serpentine rocks. These hills are higher and less eroded than the shale and limestone hills to the north and south. The vegetation is very scant in comparison with that on the shale and limestone hills. It consists mostly of tall, coarse, nearly valueless grasses and slow-growing trees. The trees grow on the concave slopes at the heads of drainageways, where there has been an accumulation of organic matter from the wash of the adjacent slopes. In many places there is insufficient vegetation to prevent erosion on this slightly erosive soil. A few gullies more than 2 feet deep have developed. They have perpendicular walls, not the bulging or convex sides characteristic of the gullies in several soils in Puerto Rico. The troughs of the gullies have smooth polished surfaces, with very few visible sand grains.

This soil, called Nipe clay, has a number of characteristics peculiar to certain tropical soils. There is very little change in physical properties from the surface to the underlying rock, which in many places ranges from 20 to 30 feet below the surface. In chemical composition the silica decreases as the aluminum oxide and iron oxide increase with depth to the serpentine rock. The serpentine rock has a higher content of silica than the soil profile and a smaller amount of aluminum oxide and iron oxide. This soil has a high percentage of clay-sized particles, which are more or less grouped in clusters. It does not have the plastic character of most clays but exhibits the physical properties of a loam. Although water penetrates this soil rapidly, it is not retained so well as in most clay soils. This soil when wet is sticky and slippery but not nearly so much so as other soils having the same percentage of clay. It dries very quickly, and cultivation is seldom delayed for any great period of time after a rain. This soil is worked when wet, and the large clods turned over slake to small crumblike particles after the first or second rain. A roadside cut shows little evidence of swelling or contracting at the extremes of moisture content. The soil, however, does dry out to low depths during long dry periods. The surface soil of an uncultivated field is very firm, but it is easily broken up to a loose mellow condition. This soil is pulled up easily with an auger, but it adheres firmly to the auger, even when dry. The material in all layers seems to have high specific gravity.

The soil profile contains many perdigones, or iron oxide pellets (fig. 141), ranging from the size of a pinhead to one-half inch in diameter. In places there are also large rounded pieces of ironstone, some 2 feet or more in diameter. Most of these, as well as the perdigones, contain more than 50 percent of iron oxide, from 15 to 25 percent of aluminum oxide, and from 2 to 5 percent of silica.

This soil is used principally for grazing. The better areas are utilized for the production of coffee and minor truck crops, and the poorer areas are idle.

The low productivity is doubtless due to several factors, among which are low bases; very little base-holding capacity, except where there has been an accumulation of organic matter; excessive permeability; and aridity during dry spells. In addition to these factors, Robinson and others (*37*) find that Laterite soils frequently contain a comparatively large quantity of magnesium and a relatively high amount of chromium and nickel. They find that some of the chro-

mium and presumably some of the nickel are exchangeable and in all probability toxic to plant growth.

A profile of Nipe clay was studied 2½ miles southeast of Mayagüez, in a smooth well-drained level area, where the mean annual precipitation is about 85 inches, the mean annual temperature about 77° F.,

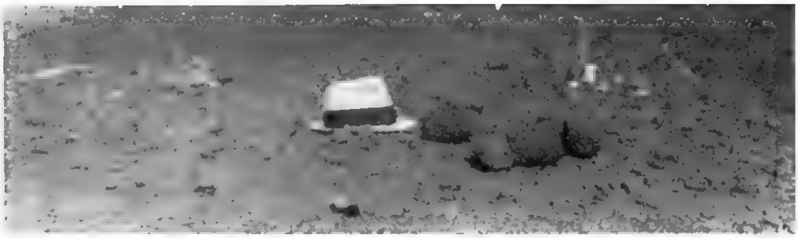

FIGURE 141.—Perdigones on the surface of Nipe clay. The surface soil has been removed by erosion, thereby exposing the upper part of the B horizon and the zone of maximum iron concretions.

Perdigones en la superficie del Nipe arcilloso. El suelo de la superficie ha sido removido por la erosión y por lo tanto la parte superior del horizonte B y la zona de máxima concentración de concreciones de hierro están expuestas.

and the vegetation a thick stand of tall coarse matojo grass. A description of this profile follows.

0 to 5 inches, dark brownish-red softly granular very slightly plastic clay. The brown color is caused almost entirely by organic matter, as the granules when crushed become very much lighter red. There is little change in color within the granules, but around all the structural units the soil is distinctly brownish red, and they have polished surfaces. This layer, although low in organic matter, has from five to eight times the amount contained in the lower layers. Apparently owing to the organic matter, this layer has a higher water-holding capacity than the layers below, even though it is less compact and contains a smaller percentage of clay. When wet to the same moisture content, the material in this layer does not dry so quickly as that in the layers below. Most of the granules range from one-eighth to one-sixteenth inch in diameter. They fit together like irregular-shaped plant cells, with numerous rounded insect casts squeezed in here and there, and loose single-grain particles mixed throughout the layer. A small percentage of the insect casts are still in nests containing from 20 to 30 each. They have more polished surfaces than the others and also have less single-grain particles fitting between them. This layer appears to have more life than the layers below, that is, it feels like soil, whereas the layers below feel like a mineral compound. There is a definite color boundary between this layer and the one below.

5 to 30 inches, purplish-red somewhat dense nonplastic clay containing very small soft and dense granules that crush readily to a fine mulch and single-grain particles. The structure granules in this layer do not appear so distinct or so numerous as in the layer above, and there seem to be more single-grain particles. This layer has more small soft iron oxide concentrations, or perdigones, ranging from the size of a pinhead to one-half inch in diameter, than either the layer above or the one below. A distinct characteristic of this layer and the layers below is that the soil, even when dry, stains clothing and flesh a purplish-red color. The color changes very little when the soil is crushed or wet. It is slick when wet and powdery when dry. Water poured on a dry clod penetrates very quickly, but the soil also dries very quickly. There are very few roots below this layer. There is little change between the material in this layer and that in the layer below, except in compactness.

30 to 60 inches, purplish-red loose friable soft faintly granular nonplastic clay. The granules are less distinct and less numerous than in the layers above.

The soil mass breaks readily from small irregular-shaped clods to a few definite soft granules and many single grains. A few of the granules are larger than those in the layers above and have more polished surfaces. Crushing and wetting have little effect on the color. The material in this layer continues to the underlying serpentine rock.

The chemical analysis of Nipe clay is given in table 60.

TABLE 60.—*Chemical analysis of Nipe clay* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Cr_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
36707	A	0–5	12.52	48.54	15.34	3.86	0.19	0.12	0.09	0.01	0.72	0.26	0.14	0.24	17.48	99.51	0	0.226
36708	B_1	5–15	8.78	57.61	16.43	3.30	(2)	.10	.02	(2)	.57	.22	.05	.22	12.80	100.10	0	.030
36709	B_2	15–50	3.00	57.79	18.69	3.54	.09	.06	(2)	.02	.42	.31	.07	.62	15.29	99.90	0	.032
36710	C_1	60	2.56	64.90	15.21	3.18	.11	.16	(2)	.06	.43	.23	.08	.72	12.82	100.46	0	.000
36711	C_2	144	2.29	63.48	12.62	5.23	(2)	.20	(2)	.03	.39	.22	.08	.55	12.40	97.49	0	.000
36712	Parent rock	156	16.89	49.57	10.45	4.67	6.02	.37	(2)	(2)	.34	.22	.04	.18	10.82	99.57	0	.000
9338	A	0–8	8.07	54.35	18.06	.61	.27	.33	.05	(2)	.78	.15	.08	.27	16.49	99.51	0	.114
9343	A	0–8	14.54	39.66	24.84	.53	(2)	.19	.11	(2)	1.40	.09	.07	.27	17.82	99.52	0	.130
9346	A	0–6	12.10	46.49	22.52	.64	(2)	.22	.07	(2)	.97	.11	.06	.23	16.96	100.37	0	.152
9349	Perdigón		1.94	55.20	22.11	1.64	(2)	.22	(2)	(2)	3.48	.14	.05	.33	14.47	99.58	0	.143
9351	do		3.84	65.01	14.02	1.88	(2)	.25	.05	.09	.90	.11	.19	.51	13.67	100.52	0	.000

[1] Sample collected by Mark Baldwin, senior soil scientist, James Thorp, soil scientist, and R. C. Roberts, soil scientist, Division of Soil Survey. Analyst, G. Edgington.
[2] Trace.

The chemical analysis of this soil type indicates that the major soil-forming processes in operation are the decrease of silica and the increase of iron oxide with depth. The surface layer has about five times the percentage of silica as does the material at a depth of 12 feet and about four-fifths as much iron oxide. The parent rock has about 25 percent more silica than the surface layer and about the same content of iron oxide and less aluminum oxide. The iron oxide concretions, or perdigones, contain more iron and aluminum, but only about one-sixth as much silica as does the surface layer. These analyses are very similar to those of Nipe clay obtained by Bennett and Allison (*8, p. 73*) in Cuba. The chemical data of the colloid and derived data undoubtedly would be very similar to the data obtained by Anderson and Byers (*1*) for Nipe clay.

Porosity and aggregation and analyses of samples of the three layers of this profile are presented in table 61.

TABLE 61.—*Porosity and aggregation of a lateritic clay* [1]

Horizon	Aggregates (0.05–2 mm.)	Particles (<0.05 mm., ultimate dispersion)	Total porosity	Air capacity	Water capacity
Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0–5	67.1	70.9	56.6	6.5	50.1
5–30	70.6	85.9	45.2	5.2	40.0
30–60	37.7	71.3	47.4	6.3	41.1

[1] Analysis made by L. D. Baver, professor of soils, University of Ohio.

It will be noted that all layers are very high in silt and clay, the second or more dense layer having the most—85.9 percent. The other two layers have about the same amount each—71 percent. Even though the second layer has the higher percentage of iron oxide concretions, it has the smaller percentage of particles greater than 0.05 mm. in size. Evidently many of the softer concretions were broken down during dispersion to clay- or silt-sized particles.

All layers have a very high state of aggregation. The second layer has the most, with 70.6 percent of its material made up of structural units. The surface layer has 67.1 percent structural units and the lower layer 37.7 percent. Examination in the field showed a more visible granulation in the surface layer than in the second layer. Most of the grains were dense, small, and soft, with very little shattering of fine powder. The third layer, however, appeared to have a high percentage of single grains and fine powder. The high state of aggregation of this soil seems to result from the fact that the large number of angular fragments into which the soil material breaks are difficult to disperse, and in reality the surface soil has the higher percentage of true granules. The high percentage of granulation in the surface soil, together with high permeability, probably accounts for the good tilth that this soil is able to maintain, even under the most adverse conditions, such as plowing when wet.

In personal communications regarding this soil, Baver says:

> I believe that we have found a clue to the apparent high porosity of the Laterites as compared with other soils. The data on porosity as we determined them were obtained with clods which had been capillarily saturated with water. The difference between total porosity and water capacity gave us the air capacity. The low air capacity determined in the laboratory would be indicative in the case of plastic soils of low permeability. However, the Laterites absorb water rapidly. This rapid water absorption must be due to a very large number of capillary pores, which take up the water rapidly and also let it evaporate or percolate downward rapidly. Since these pores are not closed by swelling they really serve similarly as air pores; when it rains they rapidly absorb water and conduct it downward. Surface tension forces within these pores are very weak as evidenced by the nonplastic condition of the soil. In a plastic soil these capillary pores would become hydrated and swell. This would result in a very slow movement of water with the possibility of the formation of dead-air spaces as a result of "choked" pores. Evidently, then, the hydration of the capillary pore must be a contributing factor in the differences between Laterites and other soils.
>
> Another factor closely related to the hydration of pores is the continuity of the capillary pores. In order to absorb water and allow it to percolate rapidly the pore space system should be continuous; when a soil becomes hydrated and swelling takes place, the continuity of the pores is broken up considerably. Such would not be the case with Laterites.
>
> If one examines, under the binocular microscope, the fragments into which the Laterite breaks up, one obtains no picture of porosity. Consequently, the pores must be very small. Microscopic observations point to a rather dense particle; more dense than the typical granule which we find in a well-granulated soil in the United States. The angularity of its fragments points to a more or less dense unit, does it not? Our data up to the present time indicate that angularity of fragments is closely associated with a dense unit.

The most interesting data in the analysis are the exceedingly low air capacity and the high water capacity in all layers. The data show, and it was also observed in the field, that the surface layer has the highest percentage of water capacity, total porosity, and air capacity.

The air capacity, however, even for the surface layer, is very low—only 6.5 percent, as compared with 20.4 percent for Ponceña clay. It is evident that the pores in the granules are both numerous and very small. There are no visible pores as is noticed in some soil layers. Water poured on the granules penetrates them very quickly, yet the granules do not increase in size, nor do they decrease when dry.

In conclusion, it may be said that this soil has a high clay and silt content, low air capacity, high water capacity, low organic-matter content, low base-holding capacity, and excessive permeability. It has very good granulation, is only slightly plastic, and has good tilth, but it is a poor agricultural soil.

The Catalina soils are lateritic but not true Laterites (*9a*). The silica-sesquioxide ratio is greater than 1. There is not a complete absence of undecomposed minerals in the upper part of the profile, and the soil is of fair agricultural value.

The Catalina soils are among the most extensive in Puerto Rico. They are the well-drained, normally developed soils in the humid uplands, derived from tuffaceous and similar rocks. Regardless of whether the thickness of the soil material is 3 feet or 30 feet, the Catalina soils are considered fairly good agricultural soils. They are, as may be expected, low in bases, but the absorbing complexes have not lost their power to retain bases, once the bases are added by amendments or deposited on the surface in the fallen-grass vegetation. The organic matter is much higher than in a true Laterite, because the vegetation is dense. It is not, however, so high as in the Rendzinas that occur within the same area and are derived from soft or medium-soft limestone.

The Catalina soils are the result of a more or less definite biochemical activity on tuffaceous or similar rocks. With a less strong biochemical activity, Cialitos or Naranjito soils are formed, and with a great biochemical activity, Los Guineos soils are developed. As stated before, the pressure of the biochemical force depends on the soil moisture. The Catalina soils may occur in areas having slightly less than 75 inches of rainfall if the relief is slightly depressed or if water is received from adjacent areas. These soils are best developed in areas of 80 or 85-inches of rainfall, where the relief is gently rolling. They occupy from 80- to 120-percent slopes in areas having from 95 to 100 inches of rainfall. Most of the level areas in the 95- to 100-inch-rainfall belt are Los Guineos soils, which also occupy many of the slopes in areas having more than 100 inches of annual rainfall.

The Catalina soils are high in clay, and as mapped they are either a clay or a stony clay, but they have several phase differentiations, depending on the degree of slope. These soils have brownish-red softly granular acid very permeable clay surface soils about 6 or 8 inches thick, which grade into red or yellowish-red friable permeable clay, which in turn grades into the parent rock, at a depth ranging from 3 to 30 feet, with very little change in physicochemical characteristics. These soils are high in alumina and iron oxide and fairly low in silica. This combination of high alumina and iron oxide and low silica ratios is generally indicative of permeable clay soils. Clays with a high silica content and low alumina and iron oxide content suggest very plastic or compact physical characteristics.

Several mechanical and chemical analyses of the lateritic soils are shown in tables 62 to 69, inclusive.

TABLE 62.—*Mechanical analysis of Catalina clay 4 miles south of Luquillo* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
580367	A	0–18	0.8	1.3	1.6	4.0	3.9	19.4	68.9	58.9	4.0
580368	B	18–28	.2	.8	.9	2.3	3.3	17.8	74.6	61.2	1.1
580369	C_1	28–68	1.4	2.9	2.2	5.0	5.4	20.9	62.2	52.0	.7
580370	C_2	68–88	.2	.3	.3	1.5	4.6	32.6	60.6	45.6	.2
580371	C_3	88–125	0	.4	.7	2.9	4.7	17.6	73.7	59.4	.4

[1] Analyst, T. M. Shaw.

TABLE 63.—*Chemical analysis of Catalina clay 4 miles south of Luquillo* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
580367	A	0–18	53.57	9.95	20.77	0.38	0.15	0.08	(2)	1.22	0.12	0.12	0.14	13.44	99.94	3.43	0	0.22
580368	B	18–28	49.28	11.28	25.27	.44	.15	.01	0.01	1.28	.13	.10	.12	11.92	99.99	1.07	0	.07
580369	C_1	28–68	57.35	10.62	20.17	.61	.11	.91	.02	1.17	.11	.07	.06	8.71	99.91	.73	0	.06
580370	C_2	68–88	53.09	10.52	23.73	.78	.07	.84	(2)	1.25	.05	.07	.07	9.55	100.02	.27	0	.02
580371	C_3	88–125	53.51	11.13	22.85	.67	.12	.75	.06	1.24	.05	.08	.06	9.66	100.18	.48	0	.03

[1] Analyst, G. Edgington. [2] Trace.

TABLE 64.—*Mechanical analysis of Cialitos clay, eroded phase, 5 miles southwest of Central Plata* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
581530a	(2)	0–½	0.1	1.0	9.3	52.0	22.4	3.9	11.3	9.8	0.1
581530	A_1	0–6	.4	.3	.6	1.8	2.4	17.3	77.3	65.1	2.1
581531	A_2	6–12	0	.1	.3	1.0	2.8	23.3	72.4	58.4	1.2
581532	B_1	12–24	0	.3	.9	2.9	4.3	31.1	60.4	45.5	.4
581533	B_2	24–36	0	.1	.3	2.3	5.7	34.6	57.1	42.1	.3
581534	C	36–48	.1	.3	.6	2.6	4.6	41.2	50.7	28.8	.1

[1] Analyst, T. M. Shaw. [2] Overwash.

TABLE 65.—*Chemical analysis of Cialitos clay, eroded phase, 5 miles southwest of Central Plata* [1]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N
		In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
581530a	(2)	0–½	9.56	73.18	8.60	0.44	0.11	0.16	(3)	5.92	0.43	(3)	0.02	1.14	99.56	0.30	0	0.02
581530	A_1	0–6	38.24	12.83	30.09	.06	.12	.06	(3)	1.10	.69	0.07	.12	16.60	99.98	3.70	0	.15
581531	A_2	6–12	43.11	12.07	29.96	.07	.08	.15	0.01	1.04	.23	.04	.11	13.16	100.03	.84	0	.02
581532	B_1	12–24	44.35	14.14	28.39	.77	.15	.20	.03	.96	.16	(3)	.12	11.22	100.49	.39	0	.03
581533	B_2	24–36	46.40	10.08	29.74	.72	.10	.16	.09	.70	.12	.03	.10	11.71	99.95	.31	0	.03
581534	C	36–48	47.43	11.23	28.33	.78	.11	(3)	(3)	.83	.16	.03	.08	11.08	100.06	.16	0	.02

[1] Analyst, G. Edgington. [2] Overwash. [3] Trace.

TABLE 66.—*Mechanical analysis of Catalina clay, 5 miles south of Río Piedras* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802128	A	0–5	0.4	1.1	1.2	3.0	4.4	22.6	67.2	61.5	6.4
5802129	B	5–20	1.4	1.2	.9	1.5	2.2	12.9	80.0	73.2	1.3
5802130	C	20–40	.1	.3	.5	2.3	4.4	22.6	69.9	56.8	.4

[1] Analyst, H. W. Lakin.

TABLE 67.—*Mechanical analysis of Cialitos clay, 5½ miles southeast of Río Piedras* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802131	A	0–6	0.8	2.0	2.0	5.4	6.7	27.8	55.2	46.7	4.5
5802132	B	6–19	0	.3	.4	1.2	2.6	30.5	64.9	51.6	.9
5802133	C	19–30	.1	1.2	2.6	6.4	6.8	23.9	58.9	48.3	.8

[1] Analyst, H. W. Lakin.

TABLE 68.—*Mechanical analysis of Alonso clay, smooth phase, one-half mile northeast of Leprocomio (leper colony)* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5802107	A	0–6	0.1	0.6	0.7	1.8	2.6	13.2	81.1	74.4	7.9
5802108	B	6–20	.1	.2	.2	.5	.8	6.9	91.4	88.4	2.6
5802109	C_1	20–32	0	.1	.1	.5	.9	12.1	86.4	80.5	1.1
5802110	C_2	32–50	0	.1	.1	.7	1.6	17.8	79.8	71.0	1.0

[1] Analyst, H. W. Lakin.

TABLE 69.—*Mechanical analysis of Malaya clay, smooth phase, south of Aguada* [1]

Sample No.	Horizon	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid	Organic matter
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
580424	A	0–4	0.4	1.1	1.7	4.3	4.5	19.4	68.7	62.0	2.7
580425	B_1	4–13	.2	.8	1.2	3.9	5.7	23.5	64.7	55.6	.6
580426	B_2	13–24	.4	.9	1.6	4.5	5.7	25.6	61.2	51.6	0
580427	C_1	24–48	0	.7	2.0	7.5	10.3	29.6	49.8	42.6	0
580428	C_2	48–60	.1	1.3	2.8	6.2	14.5	33.2	42.0	37.7	0

[1] Analyst, H. W. Lakin.

The interesting results of the chemical analyses of Catalina clay and Cialitos clay, eroded phase, are that they bear out the field observations of the difference in productivity of the two soils. Catalina clay is a fairly productive soil, but Cialitos clay, eroded phase, ranks next to Nipe clay in low crop yields. Cialitos clay, eroded phase, apparently is derived from volcanic lava. It is a very deep soil, but apparently all the parent rock has been completely weathered from the soil horizons, and little or no nutrition is available for plants.

In all these lateritic soils in the humid areas the number of micro-

biological populations must be high, as evidenced by the appearance of the surface soil, which is a mass of reworked material. There seems to be no difference between timbered and cleared areas, in appearance of the soil, but there is a difference between the soils in the arid and those in the humid districts and between saline soils and nonsalty soils. In determining the biological pressure, soil moisture seems to be more important than local edaphic conditions.

FIGURE 142.—Soil profile of Múcara silty clay loam, showing spheroidal weathering, or exfoliation.

Perfil del Múcara limo-arcilloso lómico, mostrando el desgaste esferoidal o exfoliación.

Another interesting characteristic of these permeable friable deep soils is the occurrence of more or less ovate voids about 2 inches long below a depth of 2 feet. They do not appear to have an inlet or an outlet, and most of them are surrounded by smooth more or less polished soil material. Some were observed at depths between 30 and 40 feet.

The spheroidal weathering of the rocks (fig. 142) is particularly conspicuous in this area. Apparently the percolating water seeps a short distance into the rock, and the chemical activity of the acid-

charged solution decomposes some of the cementing material of the rock. Through this process the rock mass becomes slightly crumbly, and the strain from the linear expansion, caused by the formation of more voluminous compounds, is sufficient for the soil material to peel off in veneerlike layers (fig. 143). This type of underground

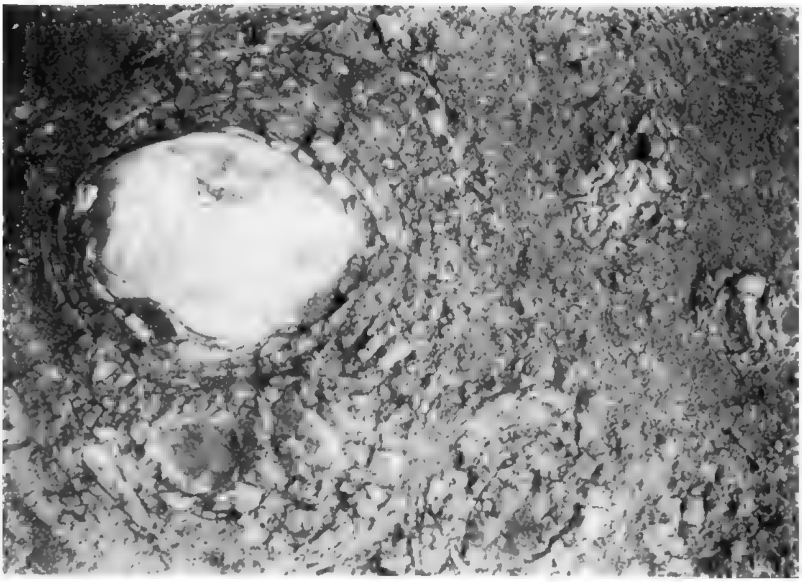

FIGURE 143.—Close-up of exfoliation.
Exfoliación vista de cerca.

exfoliation is common in dense crystalline rocks in humid tropical regions.

THE 95- TO 160-INCH+ RAINFALL BELT

The areas receiving more than 95 inches of annual rainfall include the higher, steeper, and rugged parts of the island, which are covered for the most part with vegetation of the rain-forest (fig. 144) and bryophyte types. The latter are the climax vegetation of the windswept high jagged fog-covered peaks.

In this area there is only a slight difference between soil temperature and air temperature. The evaporation where the rain forest prevails is undoubtedly less than the annual rainfall. The amount of water consumed by the dense rapid-growing vegetation is exceedingly high, and therefore the amount of soil moisture is considerably less than in areas supporting less dense vegetation and receiving the same precipitation. Probably about one-fourth of the precipitation that falls in the rain forest is lost by evaporation from the surfaces of the leaves and branches. Some of the rain is also absorbed by the plant tissues and never reaches the soil to assist in soil-forming processes. The rains are frequent, and a sufficient amount of water reaches the soil to cause continuous saturation or semisaturation. Therefore, under

a warm temperature—combined with a high rainfall—decomposition, disintegration, and leaching are uninterrupted throughout the year.

Most of the soil profiles are dominated by podzolization. This process has had an opportunity to impress on the soils its maximum pressure, owing to the favorable environmental factors, such as a dense forest cover, nearly continuous cool wet climate, and parent rock low in soluble bases.

Typical Podzols comparable to those of northeastern United States do not occur on this island. The profile of a soil observed on a 40-percent slope, at an elevation of about 3,100 feet above sea level, among areas of rough stony land in the high mountains, is somewhat similar to that of true Podzols. The samples were collected from an area one-half kilometer south of El Yunque, where the mean annual precipitation is approximately 120 inches, the mean annual tempera-

FIGURE 144.—Primeval forest with a multivariety of vegetation competing in the keenest struggle for light and existence. The glossy leaves of the tall trees cut out the light by reflection to the large-leaved short shrubs and thickly carpeted forest floor of ferns, which are struggling for breathing space in the eternal dampness, in competition with grasses, mosses, and bromeliads. The soils contain numberless micro-organisms, which consume residues of the higher plants where they contact the ground.

Bosque original con gran variedad de vegetación luchando por la luz y la existencia. Las hojas brillantes de los árboles altos reparten la luz por reflexión a las plantas pequeñas de hojas grandes y a la alfombra de helechos que cubren el suelo y que luchan por respirar bajo las condiciones de humedad alta en competencia con yerbas, musgos y bromeliaceas. Los suelos contienen numerosos microorganismos que consumen residuos de las plantas.

ture approximately 65° F., and some rain falls nearly every day. The vegetation is characteristic of a tropical rain forest and moss. The parent material is quartz diorite. Drainage is good. A description of this profile follows.

0 to 2 inches, a loose accumulation of dark-brown or black twigs and a forest mat intermixed with gray coarse-grained mineral soils.

2 to 6 inches, gray strongly acid heavy loam, loose and friable when dry but very dark gray and plastic when wet. The lower part of this layer is mottled red with hydrated and unhydrated iron oxide. Many of the old void root channels have a veneer or coating of iron oxide, and when

the soil is dissolved numerous slender cylindrical tubes of iron are exposed. The material in this layer contains some mica flakes and many insect casts.

6 to 20 inches, brown or rust-brown and yellow plastic clay loam with a high percentage of iron oxide coating the soil particles and mixed in the soil mass. The iron gives the soil a mottled appearance. Internal drainage is slow.

20 to 40 inches, yellowish-brown gritty clay loam, more friable and better drained than the material in the layer above. The structure is massive, and there are few visible roots.

40 to 80 inches, gray, brown, and black gritty friable loam containing considerable unweathered rock particles. Drainage is excellent. The material in this layer erodes when exposed to rains.

80 to 120 inches, friable partly weathered granite rocks (fig. 145) that grade into quartz diorite bedrock.

FIGURE 145.—Soil derived from granite in the humid section. The humid areas have a sufficiently moist climate to be lateritic, and they are red. They are classified as Jayuya soils. The steep areas contain less soil moisture and are more podzolic. They are gray and are classified as Utuado soils. The level ridge tops and concave gentle slopes are slightly red, in comparison with the adjacent gray soils.

Suelo rojo lateritico de la serie Jayuya, derivado de granito, en la región húmeda. Las áreas escarpadas contienen menos humedad y son más podzólicas. Son grises y pertenecen a la serie Utuado. Las crestas llanas de los montes y las laderas cóncavas son ligeramente rojas.

In places iron hardpan occurs at the base of the A horizon. It resembles bog iron and appears to have been leached from the A horizon and moved laterally to areas of better aeration where oxidation is rapid.

Throughout this high-rainfall forested belt at the heads of drainageways, near springs and seepage areas where local conditions are favorable for excessive soil moisture, the process of gleization (*23*) is dominant. The soils developed under this local environment have a nearly black 2- or 3-inch mat of leaves, overlying gray acid plastic heavy structureless clay, which continues downward for several feet. Depending on aeration and oxidation, the color at the lower depths ranges from bluish gray, indicating reduced iron compounds, to mottled rusty brown, yellow, and gray, indicating intermittent oxidation and reduction. The solubility of silica, iron oxide, and the bases are increased, owing to the high content of organic matter. If such areas of soil occupied large flats or depressions, the decaying plant remains would probably accumulate in time and form muck or peat soils.

The areas having the heaviest rainfall—160 or more inches—are so rugged, steep, and rocky that the moss-covered soil is only an inch or two thick. It is generally gray, plastic, and acid.

Intermediate between the Catalina soils and rough stony land, considerable areas of Los Guineos soils are mapped. The morphology of the profile of these soils indicates podzolization and laterization, both of which have been influential in soil development. Laterization was probably supreme during the infant stages of development, but now podzolization predominates.

Los Guineos clay is characterized by an 8- or 10-inch yellowish-brown or light-brown medium heavy slightly granular acid clay surface soil, underlain by medium-compact brownish-red fragmentary acid clay that gradually becomes mottled red, gray, and brown at a depth ranging from 2 to 4 feet, depending on the relief and the degree of erosion. In normally eroded areas the mottling occurs at lower depths, but in level areas, where neither normal nor destructive erosion occurs, the mottling is near the surface, the soil more leached, internal drainage more restricted, and productivity decreased.

SUMMARY

Puerto Rico is the smallest of the Greater Antilles. It lies about 1,400 nautical miles southeast of New York City. The greatest dimension, 113 miles, is east and west, and the average width north and south is about 41 miles. Including all the small islands under its jurisdiction, Puerto Rico has an area of approximately 3,435 square miles. The island has three principal physiographic divisions. The most extensive consists of the complex mountain ranges, which include nearly all of the interior of the island. The less extensive ones are the playa plains and the coastal plains, which circle the outer edge of the island in a ribbonlike band. The elevation ranges from sea level to 4,398 feet above, and the relief ranges from level to precipitous. Geologically the complex mountain ranges are of volcanic origin, and the coastal plains and playa plains are sedimentary. The principal rocks include several types of Tertiary and Cretaceous limestones, many kinds of shales, volcanic ash, lava, granite, andesite, sandstone, serpentine, tuff, and conglomerates.

This verdant tropical island contains an amazing pattern of contrasting natural landscapes. Many kinds of rocks have weathered to form soil materials. Some of these materials are on mountains nearly a mile high, others are near sea level, and some have been moved by

the myriad of streams from the interior, mixed with one another, and laid down again as alluvial fans and terraces. Climatic conditions range from those of the cool wet tropical rain forests of the mountains to those of the hot dry deserts. Many species of trees, grasses, and shrubs have obtained a foothold, each according to its own advantage, and with far-reaching influences on the soil. With such a multitude of landscapes there is a multitude of soils—more than 300 kinds are shown on the map. Included in a host of native and cultivated plants are more than 20 important farm crops.

Nearly all of the land is well drained and supports or originally supported a heavy growth of trees. The heaviest growth was in the humid sections, and the less heavy growth in the arid sections and on the wind-exposed slopes of the highest mountain tops. At present the vegetation varies from xerophytic plants in the arid districts to a rain forest in the areas of greatest precipitation.

Puerto Rico does not have any indigenous land mammals, but more than 1,400 different species of insects have been identified.

The population in 1940 was 1,869,245, or 549.8 people to the square mile. The density of the population, which varies greatly from place to place, creates the most serious social and economic problems confronting the insular government. A high proportion of the area consists of shallow, stony, steep, or submarginal land, and it is doubtful whether agriculture can support such a dense population and still give the people a reasonable standard of living. The population pressure forces into cultivation shallow rocky soils with 80- to 100-percent slopes.

Transportation is fairly good throughout the island, and there is regular steamship and airplane service with the United States and other countries.

Every community has some public schools, and a fairly high proportion of the younger children attend school. The census of 1935, however, shows that 35.1 percent of the people over 10 years old are illiterate.

The water supply is adequate during most of the year in most places. Considerable improvement, however, could be made in the sanitation of the drinking water. Most of the water for domestic purposes is obtained from streams.

The farm buildings are below the average of those in the United States. The sugar centrals, citrus growers' homes, and many of the coffee and tobacco plantations have modern equipment. The subsistence-crop growers, however, have very flimsily constructed buildings.

The climate is nearly ideal for a 12-month growing season. It is tropical, uniform, and oceanic; and nearly ideal conditions exist for a heavy precipitation over all but the southern one-fourth and the extreme northwestern part of the island. The average annual precipitation ranges from less than 30 inches in the southwestern part to nearly 200 inches on the high peaks in the Sierra de Luquillo. Most of the cultivated crops are irrigated in districts receiving less than 45 inches of mean annual rainfall, and sugarcane and grapefruit are irrigated in districts receiving less than 60 inches. The climate is nearly ideal for the production of such crops as coffee, sugarcane, pineapples, bananas, mangoes, coconuts, yautias, and yuca, but it is poor for alfalfa and berries. Such crops as wheat, oats, barley, apples, pears, and peaches are not grown. The climate seems to be favorable for

oxen, horses, and mules, but beef cattle, sheep, and hogs do much better in cooler climates. Rice is well adapted to the climate and to many of the soils, but it is not grown to any great extent.

Hurricanes are one of the greatest menaces to coffee growers as well as to citrus and sugarcane producers.

Puerto Rico always has been and probably always will be an agricultural island. The majority of the people have long been gardeners, and, doubtless, with the rapidly increasing population, a much larger proportion of them in the future will obtain a part of their living through the growing of subsistence crops. The principal subsistence crops now grown are bananas, corn, sweetpotatoes, beans, yautias, pigeonpeas, yuca, and ñames. These crops are relished by the natives, and when supplemented with additional rice, fish, and coffee, they constitute the main diet of the masses.

The main commercial crops are sugarcane, tobacco, coffee, grapefruit, and pineapples. Puerto Rico exported a total of $86,486,570 worth of merchandise in 1939, of which $84,782,652 worth went to the United States. Of this amount, $74,390,084 was for sugar and its byproducts. In 1935 Puerto Rico ranked seventh among the countries shipping goods to the United States, and only five countries—the United Kingdom, Canada, Japan, France, and Germany—in addition to the Territory of Hawaii, bought more goods from the United States than did Puerto Rico.

Nearly 90 percent of the fertile alluvial flood plains are used for the production of sugarcane, which is the island's most valuable crop and the basis of its most important industry, namely, the manufacturing of refined and raw sugar. The climate, soil, and people are adapted to the growing of this crop. Some of the soils are now producing a higher tonnage of cane than ever before, even after nearly 380 years of continuous cultivation to the crop. The land is generally in cane or in the process of preparation for the crop.

Such soils as the well-drained Altura and San Antón soils of the semiarid districts and the Toa and Estación soils of the humid districts are nearly ideal for the production of sugarcane. These soils, with the exception of the shallow phases, have granular friable surface soils fairly high in organic matter, with slightly heavier but friable subsoils beginning at a depth ranging from 8 to 12 inches and continuing to a depth below 5 feet before any free water or gravel is reached. The surface soils are loose and porous, and when cultivated they form an ideal seedbed. They can be worked under a fairly wide range of moisture conditions without harming their structure. The subsoil contains enough silt and clay to prevent any serious leaching of fertilizers, yet it is not so heavy as to interfere with the rapid penetration of roots.

Puerto Rico is an almost ideal place in which to study the morphology and genesis of soils, owing to the great differences, within short distances, in rainfall, relief, vegetation, and parent rock. Nearly every one of the important zonal, intrazonal, and azonal soil groups occurring in the United States is represented by one or more soil series in Puerto Rico.

The soil groups are closely associated with the rainfall belts. Beginning with the Red Desert soils along the extreme southern arid coast, the soil groups occur, with the increasing precipitation, in the following order: Reddish Brown, Reddish Chestnut, Chernozem,

Reddish Prairie, Gray-Brown Podzolic, Red and Yellow Podzolic, Reddish-Brown and Yellowish-Brown Lateritic, and Laterite. The intrazonal soils, such as the Solonchak, Wiesenböden, Half-Bog, Bog, Rendzina, and Planosol, occur throughout the island in many different rainfall belts. The same is true with the azonal soils, such as the Alluvial, Lithosols, and Sands (Dry). The intrazonal groups, such as the Solonetz, occur only in the arid rainfall belts, and the Ground-Water Podzols and Ground-Water Laterites occur only in the humid districts.

The soils of the uplands occupy nearly as much land as the combined area of all other soils. The soils in this group have a wide range of soil characteristics. They range from black to nearly white, from rich to poor, from acid to alkaline, from fine sandy loams to clays, from shallow to deep, and from young to old. The climate ranges from arid to humid, and the elevation ranges from about sea level to more than 4,000 feet above. Most of the island's coffee, oranges, bananas, forest trees, and vanilla, the greater part of the tobacco and subsistence crops, as well as pasture grass, are produced on the soils of this group. The agriculture of these soils depends to considerable extent on the depth to unconsolidated parent rock, and the soils have been placed in three subgroups, depending on their depth.

Probably the most important subgroup includes the deep soils, namely, members of the Catalina, Cialitos, Los Guineos, Alonso, Malaya, Jayuya, and Nipe series. These soils occur throughout all the humid districts of the interior. They are red or purplish red. With the exception of the Jayuya soils, they have been derived from fine-grained, volcanic, and igneous rocks, which have weathered rapidly under the warm moist tropical climate, thereby producing soils that are high in permeable clay and low in silt and sand. The iron oxide and aluminum content is high, and the silica content is low. The surface soils are acid, friable, and readily worked to a good seedbed. The subsoils, in general, are very acid, heavy, but permeable, and are adequately drained. The thickness of the subsoils and substrata increases with an increase in the mean annual rainfall and on the more gentle slopes.

Most of the soils of this subgroup occur on steep hills, and numerous V-shaped drainageways dissect the entire district. Many of the soils are planted to clean-cultivated crops, regardless of the steepness of the slopes, and because of improper management much of the surface soil is lost through erosion, although these soils are not susceptible to erosion on ordinary slopes of 10 or 15 percent. Soil development is rapid, and in many places it keeps pace with erosion. In the moist warm climate, vegetation grows rapidly, keeping erosion to a minimum, except on the improperly cultivated steep hillsides. The run-off water on most farms has a steep but short course before it empties into grass-covered or rock-bottomed drainageways. Most of these soils have some large rocks on the surface and throughout the soil layers.

Physically these soils are adapted to many crops, but, owing to a deficiency in chemical compounds, such as lime, phosphorus, and magnesium, and to their rough relief, high elevation, and in many places to their long distance from towns and highways, coffee, oranges, bananas, and timber are the most important products grown. Citrus,

pineapples, and sugarcane are important crops in the smoother lower areas adjacent to roads.

The medium-deep soils of the uplands include the hilly lands of the humid and semihumid districts that have parent rock at a depth ranging from 1 to 2 feet. Owing to the rather steep relief and thinness of the soil, such crops as tobacco and subsistence crops are better adapted to these soils than are sugarcane and citrus. Some sugarcane is grown on the best parts of these soils that are adjacent to a main road. Nearly all of the best-quality tobacco, most of the upland rice, and probably 60 percent of all the subsistence crops are produced on the soils of this subgroup. Under present agricultural conditions the success or failure of many thousands of people depends on the productivity of these soils. The value of these soils depends on the degree of slope, the amount of surface soil lost by sheet erosion, and to some extent on the number of years the land has been producing clean-cultivated crops without application of fertilizers.

This subgroup includes soils of the Colinas, Soller, and Tanamá series, developed from Tertiary limestone; of the Plata series, developed from lower Tertiary clay; of the Daguao, Múcara, Juncos, Sabana, and Naranjito series, developed mostly from massive tuffs, tuffaceous shales, and other volcanic rocks; of the Río Piedras series, developed from shale; and of the Pandura, Cayaguá, Ciales, Utuado, Teja, and Vieques series, developed from igneous rocks, mostly granite.

The requirements for successful management of farms on these soils are the use of fertilizers, sound practices for the control of erosion, proper land use, diversification of crops, and the raising of large numbers of livestock.

The shallow soils of the uplands include soils throughout the entire upland part, and therefore they have a wide range of variations. The parent rock lies at a depth of less than 18 inches. Owing to the rockiness, shallowness, unfavorable relief, dry climate, or a combination of one or more of these features, grass occupies from 60 to 65 percent of the area, trees about 15 percent, brush about 15 percent, and subsistence crops and coffee only 5 to 10 percent.

This group includes soils of the Colinas, Soller, Aguilita, Tanamá, and Ensenada series, developed from Tertiary limestone; of the San Germán and Lajas series, developed from Cretaceous limestone; of the Jácana, Descalabrado, Guayama, Daguao, Múcara, Picacho, and Naranjito series, developed from igneous rocks, mostly andesitic; of the Mariana and Yunes series, developed from shale and rhyolites; of the Juana Díaz series, developed from sandstone; of the Vieques series, developed from granite; and of the Rosario series, developed from serpentine; in addition to rough stony land, derived mostly from hard igneous rocks. The soils in this subgroup that also occur in the subgroup of medium-deep soils of the uplands are the shallow phases or steep phases of the typical soils.

Associated with the soils of the uplands are the soils of the inner plains. These soils include members of the Las Piedras, Mabí, Moca, Dominguito, Río Arriba, Santa Clara, and Camagüey series, of the humid districts, and members of the Yauco, Ponceña, Portugués, Mercedita, Barrancas, Pozo Blanco, Amelia, Río Cañas, and Cabo Rojo series, of the arid and semiarid districts. These soils, with very few exceptions, have dark sticky plastic heavy clay surface soils and plastic deep heavy subsoils. These soils are very retentive of moisture,

but they are very difficult to plow or to cultivate. They have a relief ranging from nearly level to slightly rolling.

Most of the soils in this group have a high content of organic matter in the surface soil and are better adapted to sugarcane than to any other crop grown. Probably more than 80 percent of their area is planted to this crop, and most farms are within economical hauling distances from sugar centrals. Coffee does fairly well on the well-drained sloping areas in the humid districts, but none is planted in the arid districts. Corn grows very well on these soils and is often planted on areas not irrigated or not readily accessible by oxcart roads.

Closely associated with both the soils of the coastal plains and the soils of the river flood plains are the soils of the terraces and alluvial fans. These soils have developed from material washed from the uplands and deposited along and near streams, but they are now above normal overflow. These soils have been placed in two groups, namely, medium-friable soils and compact soils.

The medium-friable soils include soils of the Torres, Vía, Lares, Fajardo, Humacao, and Mayo series, of the humid districts, and the Resolución, Llave, Arcadia, Coamo, Machete, and Vives soils, of the arid and semiarid districts. All these soils are fairly productive. They are nearly level and are used almost entirely for the production of sugarcane if they ocur within economical hauling distance from a sugar central. Yields are less than those obtained on the soils of the river flood plains. The nonirrigated areas in the arid districts are used mostly for pasture, and a few areas are in tobacco.

The compact soils of the terraces and alluvial fans include members of the Fraternidad, Paso Seco, Fé, Santa Isabel, Teresa, and Candelero series. All these soils, with the exception of the Candelero, occur in the arid or semiarid districts and are derived mostly from materials washed from limestone, tuffaceous rocks, and shale. These soils have friable granular surface soils, but the subsoils are compact and somewhat stiff. They are more difficult to cultivate than the friable soils of the terraces and alluvial fans, but they are equally productive. Nearly the entire area of the Paso Seco, Fé, Santa Isabel, and Teresa soils that is not affected with salt is irrigated and is used for the production of sugarcane. A considerable area of the Fraternidad soils is nonirrigated and is used only for pasture. Most of the Candelero soils are not irrigated, but, as they occur in humid districts, they receive sufficient precipitation for the production of sugarcane. Yields are much less than on the other soils of this subgroup because the Candelero soils are acid, leached, and derived from granite.

The soils of the coastal plains are also closely related to those of the river flood plains, but they occupy higher elevations and have better developed soil profiles than either the soils of the coastal lowlands or the soils of the river flood plains. The agricultural crops grown on the soils of the coastal plains depend to a large extent on the texture of the surface soil and the compaction of the subsoil. For this reason, the soils have been placed in four subgroups, as follows: Compact soils, friable soils, very friable soils, and loose soils.

The compact soils include soils of the Sabana Seca, Caguas, and Almirante series, the heavy-textured types of the Islote series, and the heavy-subsoil phases of the Vega Alta series. These soils are difficult to manage because of their heavy stiff nearly impermeable subsoils. Most of these compact soils occur along the northern coast and receive

an annual rainfall ranging from 60 to 75 inches. This is sufficient for the production of subsistence crops, but some of the sugarcane fields and grapefruit groves are irrigated. The surface soils are plastic and stiff. Therefore, they have a narrow range of moisture content at which cultivation can be done without injury to tilth. These soils are susceptible to drought, and yields are greatly reduced if rains are long delayed during the growing season. Cultivation is more costly than on the other coastal plains soils, and good judgment and heavy applications of fertilizers are necessary for medium returns. These soils are best adapted to sugarcane, pineapples, and subsistence crops; probably a larger acreage is in cane than in any other crop.

The friable soils of the coastal plains include the heavy-textured soils of the Bayamón, Coto, Espinosa, Matanzas, and Vega Alta series. These soils have been derived from medium-hard limestone and occur in flat or gently rolling valleys. They occur along the north coast from Aguadilla to Carolina. These soils are heavy, permeable, and neutral or acid in reaction. They have similar physical and chemical properties from the surface to the underlying limestone rock. They contain a high percentage of clay-sized particles, which are more or less grouped in clusters. When wet, these soils are somewhat sticky but not nearly so much so as other soils having the same percentage of clay. These clay soils do not swell or crack greatly at the extremes of moisture content, and cultivation is never delayed for a very long time after a rain. Although water penetrates these soils very rapidly, it is not retained so well as it is in other clay soils, and during dry periods the crops grown on them suffer from lack of moisture. These friable soils are used for the production of nearly every crop that can be grown on the island, and yields are fair. Amendments, such as lime and fertilizers, are necessary for profitable yields. Subsistence crops, sugarcane, tobacco, and grapefruit are the principal crops grown. Many thousands of people make their living from these soils, and throughout the area of their occurrence there are many houses. The farms are small, except those owned by sugar centrals.

The very friable soils of the coastal plains include the best soils used for the production of grapefruit. They include the sandy-textured members of the Vega Alta, Espinosa, Coto, Bayamón, Maleza, Islote, and Río Lajas series, all of which are derived from limestone. These soils differ from the heavy-textured soils of these series, in that they are looser, more friable, lighter textured, and have deeper surface soils and slightly more friable less heavy subsoils. Because these soils are permeable, loose, and sandy they are well adapted to the production of grapefruit and truck crops, but they are poorly adapted to sugarcane.

The loose soils of the coastal plains include the Guayabo, Corozo, Algarrobo, and St. Lucie soils. These soils contain only a small quantity of plant nutrients, because their inherent productivity is low, owing to the coarse texture of the soils, and because the soluble plant nutrients have been leached, owing to a combination of high rainfall and acid porous sandy soils low in organic matter. The better areas are easy to cultivate and respond to fertilizer and manure, but the poorer more acid soils are either in pasture or are wasteland. Sugarcane is generally a complete failure on these soils. Coconuts, pineapples, grapefruit, and subsistence crops are planted, but the

yields are very low in comparison with yields obtained on other soils of the coastal plains.

The soils of the river flood plains include the well-drained soils of the Toa, Estación, Viví, San Antón, and Altura series, in addition to riverwash; and the poorly drained soils of the Coloso, Fortuna, Vega Baja, Martín Peña, Talante, Irurena, Yabucoa, Josefa, Maunabo, Vayas, Aguirre, and Guánica series.

Water does not stand on the surface of the well-drained soils for any length of time but penetrates them rapidly. Owing to the slightly heavy subsoil, a high proportion of the percolating water reaching it is retained and utilized by the lower roots of sugarcane. These soils are nearly level. In general they occur in fairly large areas and therefore allow the use of most kinds of modern machinery. They are almost ideal for maximum agricultural utilization. This characteristic, combined with scientific and efficient management, heavy application of fertilizers, the use of excellent sugarcane varieties, and the control of insects and diseases, should develop a prosperous and contented community.

The Viví soils, derived from material washed from granitic rocks, are more leached and less productive than the other well-drained soils of the river flood plains. All these soils would be very productive for many crops, but sugarcane is more profitable than the other crops and therefore occupies nearly the entire acreage that is within economical hauling distance from a sugar central. Some of the less accessible areas are used advantageously for the production of tobacco, which yields higher on these soils than on any other soil of the island. The areas that are frequently overflowed are used extensively for malojillo grass.

The poorly drained soils of the river flood plains, which include soils of the Coloso, Fortuna, Vega Baja, Martín Peña, Talante, Irurena, Yabucoa, Josefa, and Maunabo series, of the humid districts, and of the Vayas, Aguirre, and Guánica series, of the arid and semiarid districts, are also very productive for sugarcane. As a general rule, the soils along the southern arid coast are more productive when irrigated than are the soils in the humid districts. This is probably due to the higher bases, regulated water supply, and more favorable climate for plant growth along the southern coast than along the western, northern, or eastern coasts. The poorly drained soils are slightly less productive than the well-drained soils, except during very dry years. Near large cities that have many dairies, malojillo grass can compete with sugarcane on these high-priced soils. The malojillo grass grows well on any of these soils, but a larger proportion of the most poorly drained areas are used for this grass than of the less poorly drained areas.

Closely associated with the poorly drained river flood plains are the soils of the coastal lowlands. Morphologically these soils may be placed in three groups, namely, well-drained soils, imperfectly and poorly drained mineral soils, and poorly drained organic soils. Practically all of these soils that do not have adequate drainage for the production of sugarcane contain so much salt that the vegetation is limited to mangroves and salt-resistant grasses. The cultivated areas have expensive drainage ditches, dikes, and pumps. The best of the drained areas produce fair sugarcane, but it is low in sucrose. The main enterprise on the undrained areas is the making of charcoal from the mangroves in the thickets.

The well-drained soils are those of the Cataño, Aguadilla, Palm Beach, Meros, and Jaucas series, also coastal beach and dune sand. All these soils are friable, well drained, low in fertility, very sandy, deep, and gray or brown. The Meros and Jaucas soils occur in the arid districts and are calcareous. All the other soils occur in humid areas and range from neutral to calcareous. Owing to their sandy texture, low fertility, and excessive permeability, these soils are better adapted to the production of coconuts and minor crops, such as sweetpotatoes, yuca, peanuts, and melons, than they are to sugarcane, which requires soils having high fertility and greater water-holding capacity. These soils are too near the sea for the production of a good quality of tobacco, they are too low and too dry for coffee, and most of them are too alkaline for pineapples.

The imperfectly and poorly drained mineral soils of the coastal lowlands include the Piñones, Palmas Altas, and Córcega soils, and the poorly drained phases of the Aguadilla and Cataño soils of the humid districts; and the Ursula, Serrano, and Cintrona soils of the arid districts; also Meros sand, saline phase. These soils are nearly level and may be under water several months during the year. Those occurring in the arid districts are calcareous, and many areas are affected with harmful quantities of salt. The majority of these soils are heavy plastic clays or silty clay loams that have high water-holding capacity but are difficult to plow or to drain. Most of the areas in the humid districts are acid. The productivity of nearly all of these soils depends on the effectiveness of an artificial drainage system. Areas that are adequately drained are used for the production of sugarcane, which yields less than on the poorly drained soils of the river flood plains. Most of the undrained areas are used advantageously as malojillo grass pastures. The swamp areas are used only for the growing of mangroves.

The poorly drained organic soils include Tiburones muck; Saladar muck; Saladar muck, shallow phase; peat; peat, shallow phase; Piñones clay, peaty-subsoil phase; and Reparada clay.

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SOIL LEGEND
PUERTO RICO

UNIVERSITY OF PUERTO RICO
AGRICULTURAL EXPERIMENT STATION
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NOTE: A subscript after each of the above symbols indicates presence of sodium or potassium carbonates (true or "black" alkali). Locations of borings and result of field tests shown thus: The upper figure shows the percentage concentration in the surface foot. The lower figure shows the average concentration to a depth of four or five feet.

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SOIL MAP
EAST-CENTRAL SHEET
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SOIL MAP

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Scale 1/50000
Kilometers
Miles

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